THE INTERNATIONAL DICTIONARY OF PHYSICS AND ELECTRONICS

D. VAN NOSTRAND COMPANY, INC.

PRINCETON, NEW JERSEY

TORONTO LONDON

NEW YORK

D. VAN NOSTRAND COMPANY, INC.
120 Alexander St., Princeton, New Jersey (*Principal office*)
257 Fourth Avenue, New York 10, New York

D. VAN NOSTRAND COMPANY, LTD.
358, Kensington High Street, London, W 14, England

D. VAN NOSTRAND COMPANY (Canada), LTD.
25 Hollinger Road, Toronto 16, Canada

Library of Congress Catalogue Card No. 56-11759

PRINTED IN THE UNITED STATES OF AMERICA

CONTRIBUTING EDITORS

WALTER C. MICHELS, *Senior Editor*
Bryn Mawr College

NIEL F. BEARDSLEY
Ohio State University
Wright Air Development Center, USAF

R. T. BEYER
Brown University

H. C. CORBEN
Carnegie Institute of Technology;
Ramo-Wooldridge Corporation

ROBERT LINDSAY
Southern Methodist University

ROBERT B. LINDSAY
Brown University

J. C. MAY
Yale University

K. MENDELSSOHN
University of Oxford

GEORGE MURPHY
New York University

CHESTER H. PAGE
National Bureau of Standards

RUDOLPH SHER
Brookhaven National Laboratory

BENSON R. SUNDHEIM
New York University

A. A. TOWNSEND
University of Cambridge

A. D. YOFFE
University of Cambridge

J. M. ZIMAN
University of Cambridge

PREFACE

In planning this dictionary of physics and electronics the editor and contributors have constantly held before themselves the ambitious objective of serving the greatest possible number of those people who are working with physics. This group includes not only professional physicists, and those intending to make physics their profession, but also the far greater number of workers in other fields who have frequent need for information about terms used in physics. Among these are men whose primary activity lies in some other field of science than physics, such as chemistry or biology, as well as engineers and technologists.

Obviously, the attempt to realize so ambitious a program in one volume has necessitated a number of compromises and many arbitrary decisions. The compromise on units is explained in the extended Introduction to this Dictionary, in which the subject of units is dealt with, it is hoped, at sufficient length to overcome any confusion that may confront the reader on this score. The question of level of difficulty has been answered as far as possible by including in most definitions both formal and discursive statements and entries. This policy serves the two-fold purpose of giving the reader both a "simple" explanation and a more rigorous definition at the same time that it lightens the general tone of the work for those who do not have an extensive mathematical background. The needs of this particular type of reader have also been served by including definitions of many of the more common mathematical terms encountered in present-day physics.

The terms defined in this book include laws, relationships, equations, basic principles and concepts, as well as the most widely used instruments and apparatus. In short, this treatment comprises the terms both of pure science and of its applications. The fields covered include mechanics, heat and thermodynamics; low temperature physics; the properties of gases, liquids, and solids; acoustics; optics; electricity; electronics; nuclear physics; mathematical physics; and representative topics in relativity and a few other of the more advanced and specified fields. Further to serve the needs of the teacher, student and worker in the field of physics, as well as in related fields, a considerable number of terms have been included from the subject-areas bordering on physics, not only mathematics, but physical chemistry, applied electronics, applied electricity, etc. Obviously, all the terms in pure and applied physics cannot be defined adequately in a book, or for that matter in a library. The objective of editors and contributors has been the more modest one of providing a book useful as a general reference in physics, helpful even to the specialist in regions outside of his domain of specialized knowledge.

Further to facilitate the use of this book for reference purposes, a comprehensive plan of cross referencing has been devised. Wherever, in the definition of a given term other words or expressions are used for which cross reference is necessary, those words or expressions are printed in bold-face type, so that the reader need only to turn to the corresponding entry to find the additional information he may need. This plan has proved most successful in other books, and it should increase materially the reference value of this Dictionary. When the term to which reference is made has more than one meaning, and possible confusion might result, the usage intended in the given case is designated by a corresponding bold-face number following the term in the original entry.

The general choice of subject matter has been, as might be expected, the question on which the largest number of arbitrary decisions has been necessary. The policy has been followed of including, wherever possible, all definitions which have been established or recommended by established groups. For such definitions the editor and contributors wish to express their deep indebtedness to the Acoustical Society of America, the Optical Society of America, the American Standards Association, the Institute of Radio Engineers, the National Research Council and other societies and organizations who have established clear statements of basic physical concepts and relationships and definitions of equipment used in pure and applied physics.

It is the hope of all who have worked on this book that it may contribute in some measure toward a widening of interest in the field of physics and toward an extension of the range of its applications. Whether the Dictionary will continue to fulfill this hope depends in a large part on the willingness of our readers to criticize our work and to suggest additions and improvements. With such aid, future issues of this Dictionary can achieve the highest standard of usefulness.

THE EDITORS

INTRODUCTION

UNITS AND DIMENSIONS

Policies Followed in This Volume

Since physics is a quantitative science, its definitions should be exact and unambiguous. It has become increasingly apparent during the last half century that exactness in the definitions of physical terms in general can be best achieved, and that ambiguity can be best avoided, if definitions are operational, i.e., if each definition indicates a process by which the defined quantity can be measured. The process of measurement specified by the definition need not be the one used practically, but the latter must always be reducible in principle to the former. For example, the *distance* between two points is defined as the number of times that a specified measuring rod must be successively applied along a straight line joining the two points in order to cover this line completely. It would hardly be practical to measure the distance from the earth to the moon by this process, but the method of triangulation, by which this distance is measured, may be shown to be equivalent to the successive application of a rod.

Every physical measurement involves the comparison of two quantities of the same nature, e.g., two lengths, two electrical currents, etc. The same results will be achieved by two different observers only if they have agreed to use the same standard as one of these quantities. To provide such standards, certain fundamental units have been established by custom, by national legislation, and by international agreement. The definitions of these fundamental units throughout this volume are consistent with the legal definitions or with accepted custom in the United States and in Great Britain. In a few cases, such as that of the inch, the two countries have definitions which do not agree precisely; in these instances both definitions are given.

The specification of a physical quantity must tell both what standards were used in the measurement and how the quantity compares with these standards. The quantity is therefore expressed as the product of a pure number, giving the latter piece of information, and a unit which gives the former. Two equal quantities may be represented by quite different numbers if they are measured in different units. Thus:

$$1 \text{ mile} = 5280 \text{ feet} = 1609 \text{ meters.}$$

All quantities which can be expressed in the same units are said to have the same physical dimensions. Thus two square miles and ten acres, while they are not equal, have the same dimensions, those of area, or of length squared.

The great majority of physical quantities can be measured in terms of derived units, which are defined in terms of the fundamental units. Thus *velocity* is defined as the time rate of change of position and is determined by a measurement of the change of position, i.e., a length, l, during a time interval, t. The average velocity during this interval is $v = l/t$. The unit of velocity is therefore a unit of length divided by a unit of time, such as feet/second, miles/hour,

meters/minute, etc. When quantities measured in terms of derived units are given in this dictionary, their dimensions in terms of fundamental units are usually specified. To avoid the complexity that would result if every quantity were expressed directly in terms of fundamental units, the dimensions are often expressed in terms of derived units intermediate between those of the defined quantity and the primary standards. Thus the **Planck constant,** h, is given dimensions of erg seconds. The erg itself has the dimensions of force times distance, and force has the dimensions of a mass times a length divided by the square of a time. Hence, letting m, l, and t represent mass, length, and time, respectively, we find that the dimensions of the Planck constant are

$$[h] = [(ml/t^2)(l)(t)] = [ml^2/t],$$

or that it could be expressed in units of the gram centimeter squared per second.

Which physical quantities should be chosen as fundamental, or even how many should be chosen, are matters of choice and convenience. This is true because most physical laws express proportionalities, rather than equalities. As an example, we may consider the usual statement of the **Newton second law of motion,** that the acceleration, a, produced in a body of mass m by a force, f, is directly proportional to the force and inversely proportional to the mass. This law may be written as

$$a \propto f/m.$$

It is usually convenient to change this proportionality to an equation by the insertion of a constant of proportionality, K:

$$Ka = f/m.$$

This equation involves three physical quantities, a, f, and m. If all three of these are defined arbitrarily, either as fundamental units or in terms of derived units, the dimensions of K will be determined by the equation. On the other hand, any two of the physical quantities may be defined arbitrarily, and a further arbitrary choice may be made as to the dimensions and magnitude of K. The equation may then be used as a defining equation of the third quantity. Whether one or the other choice is convenient depends on the problem to which Newton's second law is being applied. The consequences of the various possible choices in this case are discussed below, in the section on Mechanical Units.

Each time that an arbitrary choice such as that just discussed is made, a new system of units is established. Each of these systems is self-consistent but the various systems are not necessarily consistent with each other. Whenever a choice exists as to the system of units in which a quantity may be defined, this Dictionary has either given two or more definitions, specifying the system in which each is appropriate, or has stated the dimensions of the quantity in such a way that the definition may be modified when a different system is employed. The inclusion of all of the hundred or more systems that have been used would have resulted in confusion, hence only a limited number of systems are accepted here. These systems are listed in the next few pages, and the relations among them are outlined.

Nearly all physical measurements can be reduced to the measurement of mechanical, thermal, or electromagnetic quantities, or to some combination of these. The systems of units which are used for each are treated below.

Mechanical Units

All mechanical measurements involve the motion of material bodies, described in terms of space and time coordinates. Hence length and time are almost universally chosen as fundamental quantities. The present standard of time is the *mean solar day,* defined as the average period between two successive transits of the sun across the meridian at any given spot on the earth's surface. The most commonly used unit of time is the *second,* defined as 1/86,400 part of a mean solar day.* Two independent length standards, the *meter* (M) and the *yard* (yd), are in common use. From the former is derived the *centimeter* (1 cm = 1 M/100) and from the latter, the *foot* (1 ft = 1 yd/3). The fundamental length units used in this volume will be limited to the meter, the centimeter, the inch, and the foot.†

In physics, chemistry, and electrical engineering, as well as in much of mechanical engineering, the commonly employed systems of mechanical units use length, mass, and time as fundamental quantities. These are known as *length-mass-time* systems. Three such systems, the *meter-kilogram-second* (MKS), the *centimeter-gram-second* (cgs), and the *foot-pound-second* (f lbm s) systems, are used in this volume. In all three systems the constant of proportionality in Newton's law is chosen as a dimensionless quantity of unit magnitude.

In structural engineering and in some mechanical engineering applications, forces play a more important part than do masses. Systems which use length, force, and time as fundamental units are therefore convenient. The only length-force-time system which is used here is the *foot-pound-second* system. The unit of force, the *pound* (*force*), is defined as the weight of a pound mass at a point on the earth's surface at a point where the acceleration due to gravity is 32.174 ft/sec^2. In this system the unit of mass, the *slug,* is a derived unit, equal to 1/32.174 lbm. In order that confusion may not be caused by the use of the pound both as a unit of mass and as a unit of force, the pound (mass) is abbreviated as lbm, the pound (force) as lbf.

A third type of system defines both the mass and force as well as units of length and time. In such *mass-force-length-time systems,* the constant of proportionality in Newton's second law takes on dimensions and a non-unitary value. Two such systems, the lbm-lbf-ft-sec and the gm-gf-cm-sec system are employed here. The abbreviation gf is used to indicate a *gram* (*force*), the unit of force, which is defined as the weight of a one-gram mass under the action of a gravitational acceleration of 980.665 cm/sec^2.

The more important units in each of the six systems and the relations among these units are shown in Table 1. As an example of the use of this and similar

* This is not a completely satisfactory definition, because tidal action is gradually slowing the rotation of the earth. It therefore seems probable that the second will be redefined in the near future, as a specified multiple of a period of vibration of some particular molecule, probably ammonia.

† Two slightly different definitions of the foot are in use in the United States. They disagree with each other and with the definition used in Great Britain by a few parts in a million. The British foot is defined as exactly one-third of an Imperial yard; the National Bureau of Standards and the U.S. Coast and Geodetic Survey define the foot as exactly 1200/3937 meter, the American Standards Association, B18.1, 1933 and 1947, defines the foot as exactly 0.3048 meter. The differences are significant only in refined measurements, the relative lengths of the three feet defined above being

0.914399:0.914402:0.914400.

It seems possible that both the meter and the yard may be redefined within a few years in terms of the wavelength of a particular spectral line, instead of as material standards.

tables, suppose that a moment of inertia is specified as 1050 gm cm², and that it is desired to express this quantity in the f lbm s system. The use of conversion factors from the table shows that

$$1050 \text{ gm cm}^2 \times \frac{2.205 \text{ lbm}}{1000 \text{ gm}} \times \frac{(3.281 \text{ ft})^2}{\text{M}^2} \times \frac{\text{M}^2}{(100 \text{ cm})^2} = 0.002492 \text{ lbm ft}^2.$$

TABLE 1 RELATIONS AMONG THE SYSTEMS OF MECHANICAL UNITS

Quantity	MKS System	Equivalents in Other Systems				
		cgs System	f lbm s System	f lbf s System	f lbm lbf s System	cm gm gf s System
Length	1 Meter	10^2 cm	3.281 ft	3.281 ft	3.281 ft	10^2 cm
Mass	1 Kilogram	10^3 gm	2.205 lbm	70.94 slug	2.205 lbm	10^3 gm
Density	1 K/M³	10^{-3} gm/cm³	$62.43(10)^{-3}$ lbm/ft³	2.009 slug/ft³	$62.43(10)^{-3}$ lbm/ft³	10^{-3} gm/cm³
Force	1 Newton	10^5 dyne	7.015 poundal	0.2180 lbf	0.2180 lbf	102.0 gf
Work (Energy)	1 Joule	10^7 erg	23.02 ft poundal	0.7153 ft lbf	0.7153 ft lbf	$1.020(10)^4$ gf cm
Power	1 Watt	10^7 erg/sec	23.02 ft poundal/sec	$1.341(10)^{-3}$ horsepower	0.7153 ft lbf/sec	$1.020(10)^4$ gf cm/sec

Thermal Units

Thermal measurements involve, in addition to the mechanical quantities outlined above, the specification of temperature. Two temperature scales are in common use, both being defined in terms of measurements made with a mercury-in-glass thermometer and both having the freezing and boiling points of pure water at normal atmospheric pressure as fixed points. The *Celsius*, or *Centigrade*, scale is obtained if the freezing point is taken as zero degrees and the boiling point as 100 degrees.* The Fahrenheit scale is obtained if these points are taken as 32 degrees and 212 degrees, respectively. Thus the *degree Celsius* (°C) is the temperature difference which causes the mercury in a thermometer to expand by 0.01 as much as it expands between the freezing and boiling points. The *degree Fahrenheit* (°F) is defined similarly, and is therefore 5°C/9.

The original definitions of the Celsius and Fahrenheit scales would limit the measurement of temperature to the range in which the mercury-in-glass thermometer can be used. These scales are extended upward and downward with

* The definition given is that in common use at present. It is in close agreement with the recommendation of the International Union of Pure and Applied Physics in 1955 that the triple point of water (i.e., the temperature at which ice, water and water vapor can exist in equilibrium) be defined as 273.16°K and be used as the basis of determining the size of one degree Kelvin. This recommendation would make the Kelvin scale fundamental, rather than the Celsius scale.

the help of the gas thermometer and of well established thermodynamic laws. The *Kelvin*, or *absolute*, temperature scale is based on the second law of thermodynamics, and is independent of the properties of any particular substance, except for the definition of the size of a degree. Its zero is the lower limit of temperature, which can be approached but never reached, and the size of a *degree Kelvin* (°K) is taken in such a way that the difference of the temperatures of the freezing and boiling points of water shall be 100°K. Careful measurements have demonstrated that the zero of the Celsius scale is at 273.16°K. The *Rankine* temperature scale is an absolute scale in which the degree (°R) is matched to the Fahrenheit thermometer.

Since heat is a form of energy, any of the mechanical units of energy, such as the erg, joule, or foot pound, may be used to measure quantity of heat. Other units, based on the thermal properties of water, had become well established before the first law of thermodynamics was enunciated. The use of these units persists, and several of them are used interchangeably with the mechanical units in this dictionary. The most widely accepted is the *calorie* (cal) which was originally defined as the heat necessary to raise the temperature of one gram of water through a temperature increase of one degree Celsius. This definition makes the unit depend on the initial temperature of the water, so the calorie has been redefined as equal to 4.1840 joules. The *kilocalorie* or *large calorie* (kcal) is exactly 1000 cal. The *British thermal unit* (BTU) is the heat required to raise the temperature of one pound of water through one degree Fahrenheit.

The four basic systems of thermal units employed in this volume are summarized in Table 2. Relations among derived units, such as those of specific heat,

TABLE 2. RELATIONS AMONG THERMAL UNITS

Quantity	MKS °C System	Equivalents in Other Systems			
		MKS °K System	cgs °K System	f lbm s °F System	f lbm s °R System
Temperature difference	1°C	1°K	1°K	1.80°F	1.80°R
Temperature	x°C	$(273.16 + x)$°K	$(273.16 + x)$°K	$(32 + 9x/5)$°F	$(491.7 + 9x/5)$°F
Energy	1 joule = 0.2390 cal	1 joule	$(10)^7$ erg	$9.478(10)^{-4}$ BTU 0.7153 ft lbf	$9.478(10)^{-4}$ BTU

entropy, etc., may be obtained by methods identical with that outlined in connection with Table 1. For example:

$$\frac{0.0235\ \text{BTU}}{°\text{F}} = \frac{0.0235\ \text{BTU}}{°\text{F}} \times \frac{1\ \text{joule}}{9.478(10)^{-4}\ \text{BTU}} \times \frac{1.80°\text{F}}{1°\text{K}} = \frac{44.6\ \text{joule}}{°\text{K}}.$$

Electromagnetic Units

At least eight or ten different systems of electrical and magnetic units are in common use. Each of these is based on a particular choice of a constant of proportionality in an experimentally verified physical law. Some systems start

with Coulomb's law, which states that the force, f, between two electrical charges, q_1 and q_2, separated by a distance r in empty space is directly proportional to the product of the charges and inversely proportional to the square of the distance between them, i.e.:

$$f = K_e q_1 q_2 / r^2,$$

where K_e is a constant that may be chosen for convenience. Such systems are known as electrostatic systems. The choice of K_e as unity and dimensionless, together with the use of the dyne and the centimeter as units of force and length, leads to the *cgs electrostatic system* in which the unit of charge, the *statcoulomb*, is the charge which repels an exactly similar charge, separated from it by one centimeter *in vacuo*, with a force of one dyne. This system is frequently called the esu system. Another choice, which is sometimes convenient, takes K_e as a dimensionless constant equal to $1/4\pi$. This leads to the *rationalized cgs electrostatic* system. In either of the two systems, charge has the dimensions of dyne$^{1/2}$cm, equivalent to cm$^{3/2}$gm$^{1/2}$sec^{-1}. All other electrical quantities also have identical dimensions in the two systems, although the sizes of their units differ. In order that ambiguity may be avoided, all quantities stated in esu in this dictionary are given values consistent with the unrationalized system and all formulae involving esu are written in the form appropriate to that system

In distinction to the electrostatic systems are the *electromagnetic systems* (emu systems), which start with the law of attraction between currents. If two currents of magnitudes I_1 and I_2 flow in long parallel wires, separated by a distance *d in vacuo,* they attract each other with a force per unit length, f_l, given by

$$f_l = K_m I_1 I_2 / d.$$

Here the constant of proportionality, K_m, may be chosen quite arbitrarily The *cgs emu system* is based on the dyne and the centimeter as units of force and length and on the choice of K_m as a dimensionless constant of magnitude two. The emu of current, the *abampere*, then has the dimensions of dyne$^{1/2}$, or cm$^{1/2}$gm$^{1/2}$sec^{-1}.

The emu of charge, the *abcoulomb*, is defined as the charge which passes a given surface in one second if a steady current of one abampere flows across the surface. Its dimensions are therefore cm$^{1/2}$gm$^{1/2}$, which differ from the dimensions of the statcoulomb by a factor which has the dimensions of a speed. This relationship is connected with the fact that the ratio $2K_e/K_m$ must have the value of the square of the speed of light in any consistent system of units. It follows further that

$$1 \text{ abcoulomb} = 2.998(10)^{10} \text{ statcoulomb},$$

the speed of light in vacuo being $2.998(10)^{10}$ cm/sec.

A *rationalized emu* system, in which K_m is taken as $1/2\pi$, has also been developed, but it is not used in this volume.

The electrostatic system is convenient for problems in which the principal equations may be deduced from Coulomb's law. Similarly, the electromagnetic system is convenient for problems involving the interactions between currents. In many physical problems, both electrical and magnetic interactions take place. Both systems suffer from certain inconveniences under these circumstances, and the *Gaussian* system of units has, as a result, gained wide popularity. In this system, magnetic quantities, such as magnetic field strength and magnetic flux

density, are expressed in emu, while electric field strength, charge, and current are expressed in esu. To maintain self-consistency, it is essential that a factor c, the speed of light, be introduced into many of the equations which describe electromagnetic phenomena. It is our practice, whenever confusion might otherwise arise, to state equations appropriate both to the simple systems (esu, emu, etc.) and to the mixed Gaussian system. Whenever the factor c occurs in such equations, it is the speed of light *in vacuo,* having the dimensions of cm/sec, not a pure number. A *rationalized Gaussian* system is sometimes employed, but it is not used in this volume.

In all of the systems discussed thus far, cgs mechanical units have been employed. New systems of electrical units evolve if other sets of mechanical units are substituted. Only two such systems, both based on the mks mechanical units, have found wide acceptance. Of these two, only the *rationalized mksa* system is used here. The arbitrary choice which leads to this system is that of the unit of current. The *absolute ampere* is defined as exactly one-tenth of an abampere. With this choice, and with the newton and the meter as the units of force and length, the two constants which were chosen arbitrarily in the esu and emu systems are determined and have dimensions. They become:

$$K_e = 8.986(10)^9 \; km^3s^{-4}a^2,$$

and

$$K_m = 2.000(10)^{-7} \; kms^{-2}a^2.$$

One virtue of the mksa system is that nearly all of the electrical quantities expressed in it coincide closely with the *practical system* of units which grew up during the nineteenth century. Thus the volt, the ampere, the henry, the farad, and the ohm are all units in the mksa system. In fact, the legal electrical units have been fixed by international agreement since 1950 as the absolute mksa units. Prior to that time, the *International system* of electrical units had been used. This system had been intended to coincide with the absolute system, but had been defined in terms of fixed standards, which are slightly in error. There are therefore small differences between the two sets of electrical quantities, of the order of a few parts in ten thousand. Because many quantities stated in the literature are expressed in international units, these obsolescent definitions are included here.

One more remark needs to be made in regard to the dimensions of certain electromagnetic units. Two electrical quantities, the field strength **E** and the displacement **D**, are closely related, as are two magnetic quantities, the field strength **H** and the flux density **B**. In the electrostatic system, **E** and **D** have the same dimensions and are identical in magnitude in empty space; in the electromagnetic system, **H** and **B** have a corresponding relation. Thus in air, the electrical properties of which are practically those of empty space, the flux density is identical with the magnetic field strength if both are expressed in emu. The old unit of field strength, the *gauss,* has therefore been used to denote both **H** and **B**. In an attempt to avoid confusion, the name of the emu unit of **H** was changed to the *oersted* about 20 years ago. The gauss had become so well established, however, that it is still used, and its meaning (either oersted or maxwell per square cm) must be judged from context.

The relations among the five systems of electrical units which we employ are displayed in Table 3.

TABLE 3 RELATIONS AMONG THE SYSTEMS OF ELECTRICAL AND MAGNETIC UNITS

(The dimensions of the various quantities are shown in square brackets)

Quantity	mksa (Absolute) System	Equivalents in Other Systems			
		Old International System	cgs esu System	cgs emu System	Gaussian System
Permittivity of empty space (ϵ_0)	$8.855(10)^{-12}$ Farad/M $[m^{-3}k^{-1}s^4a^2]$	$8.859(10)^{-12}$ Int Farad/M	1 [Dimensionless]	$1.1126(10)^{-21}$ $[cm^{-2}s^2]$	1 [Dimensionless]
Permeability of empty space μ_0	$1.2566(10)^{-6}$ Henry/M $[mks^{-2}a^{-2}]$	$1.2560(10)^{-6}$ Int Henry/M	$1.1126(10)^{-21}$ $[cm^{-2}s^2]$	1 [Dimensionless]	1 [Dimensionless]
Charge (Q)	1 Coulomb $[sa]$	1.000165 Int Coulomb	$2.998(10)^9$ Statcoulomb $[cm^{3/2}gm^{1/2}s^{-1}]$	0.1 Abcoulomb $[cm^{1/2}gm^{1/2}]$	$2.998(10)^9$ Statcoulomb $[cm^{3/2}gm^{1/2}s^{-1}]$
Potential difference (V)	1 Volt $[m^2ks^{-3}a^{-1}]$	0.999670 Int Volt	$3.336(10)^{-2}$ Statvolt $[cm^{1/2}gm^{1/2}s^{-1}]$	$(10)^8$ Abvolt $[cm^{3/2}gm^{1/2}s^{-2}]$	$3.336(10)^{-2}$ Statvolt $[cm^{1/2}gm^{1/2}s^{-1}]$
Current (I)	1 Ampere $[a]$	1.000165 Int Ampere	$2.998(10)^9$ Statampere $[cm^{3/2}gm^{1/2}s^{-2}]$	0.1 Abampere $[cm^{1/2}gm^{1/2}s^{-1}]$	$2.998(10)^9$ Statampere $[cm^{3/2}gm^{1/2}s^{-2}]$
Resistance (R)	1 Ohm $[m^2ks^{-3}a^{-2}]$	0.999505 Int Ohm	$1.1126(10)^{-12}$ Statohm $[cm^{-1}s]$	$(10)^9$ Abohm $[cms^{-1}]$	$1.1126(10)^{-12}$ Statohm $[cm^{-1}s]$
Electric displacement (D)	1 Coulomb/M^2 $[m^{-2}sa]$	1.000165 Int Coulomb/M^2	$2.998(10)^5$ Statcoulomb/cm^2 $[cm^{-1/2}gm^{1/2}s^{-1}]$	$(10)^{-5}$ Abcoulomb/cm^2 $[cm^{-3/2}gm^{1/2}]$	$2.998(10)^5$ Statcoulomb/cm^2 $[cm^{-1/2}gm^{1/2}s^{-1}]$
Capacitance (C)	1 Farad $[m^{-2}k^{-1}s^4a^2]$	1.000495 Int Farad	$8.988(10)^{11}$ cm [cm]	$(10)^{-9}$ Abfarad $[cm^{-1}s^2]$	$8.988(10)^{11}$ cm [cm]
Magnetic dipole moment	1 Ampere M^2 $[m^2a]$	1.000165 Int Ampere M^2	$3.336(10)^{-6}$ Statmaxwell/cm $[cm^{1/2}gm^{1/2}]$	$(10)^5$ Maxwell/cm $[cm^{5/2}gm^{1/2}s^{-1}]$	$(10)^5$ Maxwell/cm $[cm^{5/2}gm^{1/2}s^{-1}]$
Magnetic field strength (H)	1 Ampere turn/M $[m^{-1}a]$	1.000165 Int Ampere turn/M	$3.767(10)^8$ Statoersted $[cm^{1/2}gm^{1/2}s^{-2}]$	$1.257(10)^{-2}$ Oersted $[cm^{-1/2}gm^{1/2}s^{-1}]$	$1.257(10)^{-2}$ Oersted $[cm^{-1/2}gm^{1/2}s^{-1}]$
Magnetic flux density (B)	1 Weber/M^2 $[ks^{-2}a^{-1}]$	0.999670 Int volt S/M^2	$3.336(10)^{-7}$ Statmaxwell/cm^2 $[cm^{-3/2}gm^{1/2}]$	$(10)^4$ Maxwell/cm^2 $[cm^{-1/2}gm^{1/2}s^{-1}]$	$(10)^4$ Gauss $[cm^{-1/2}gm^{1/2}s^{-1}]$
Inductance (L)	1 Henry $[m^2ks^{-2}a^{-2}]$	0.999505 Int Henry	$1.1126(10)^{-12}$ Stathenry $[cm^{-1}s^2]$	$(10)^9$ cm [cm]	$(10)^9$ cm [cm]
Power	1 Watt $[m^2ks^{-3}]$	0.999835 Int Watt	$(10)^7$ erg/s $[cm^2gms^{-2}]$	$(10)^7$ erg/s $[cm^2gms^{-2}]$	$(10)^7$ erg/s $[cm^2gms^{-2}]$

Units Not Included in Absolute Systems

Although nearly all physical measurements, from those of the dimensions of the universe to those involving nuclei of atoms, *can be* expressed in terms of the mechanical, thermal, and electromagnetic systems discussed above, many physical quantities *are* expressed in terms not reducible to any of the systems given. During the early development of many parts of physics, measurements of the relative properties of various substances were all that were possible or required. Hence terms like specific gravity, specific heat, candle power, and curie have come into the literature of the subject. As the art of measurement progresses, such terms are usually redefined in such a way that they acquire absolute meanings. It has been our practice to give both definitions of terms of this type, with some indication of when the change in meaning took place.

Many special systems of units are convenient for particular calculations. Thus, many atomic calculations are facilitated if the electronic charge, the radius of the lowest Bohr hydrogen orbit, and mass of the electron are taken as fundamental units of charge, length, and mass, respectively. Whenever units of this type are used in this dictionary, they are expressed in terms which allow cross reference to be made to the quantities involved, hence they can be converted into absolute units.

A

A. (1) Linear acceleration (**a**). (2) Mean sound absorption coefficient (a). (3) Element argon (A). (4) Angstrom unit (A or Å). (5) First van der Waals constant (a). (6) Chemical activity (a). (7) Accommodation coefficient (a). (8) Amplification of amplifier (A). (9) Amplitude (A). (10) Refracting angle of prism (A). (11) Area (A). (12) Specific rotation of light $[a]$. (13) Free energy, Helmholtz, which is also known as isothermal work function, total (A), per unit mass (a), per mole (a, A or A_m). (14) Factor in Richardson-Dushman equation (A). (15) Width of slit (transparent portion) (a). (16) Atomic weight (A). (17) First Cauchy constant (A). (18) Strength of simple acoustic source (A). (19) Magnetic vector potential (**A**). (20) Bohr radius (a_1). (21) Radius of acoustical tube, disc or membrane (a).

A+, A−. Terminal markings for sources of filament voltages in electronic equipment. (See **A supply.**)

A BATTERY. Power source for **filaments** in battery-operated electronic equipment.

A SUPPLY. The source of the heating current for the cathode of an electronic tube. In the early days of radio the various voltages needed to operate a receiver were obtained from batteries, called A, B and C batteries, supplying the filament, plate and grid voltages respectively. These letter designations have carried over to the present-day sources, although the voltages are usually obtained now from an a-c source, either directly as in the case of the A supply or indirectly for B and C voltages.

AB-. A prefix attached to the names of the practical electrical units to indicate the corresponding unit in the cgs electromagnetic system (emu), e g , abampere, abvolt.

AB PACK. A combined package of **A and B batteries.**

ABAMPERE. The cgs **electromagnetic unit** of current. It is that current which, when flowing in straight parallel wires 1 cm apart in free space, will produce a force of 2 dynes per cm length on each wire. One abampere is ten amperes.

ABBE CONDENSER. A compound **lens** used for directing light through the object of a compound **microscope.** All the light enters the object at an angle with the axis of the microscope.

ABBE NUMBER. The reciprocal of the **dispersive power** of a material.

ABBE REFRACTOMETER. See **refractometer, Abbe.**

ABBE SINE CONDITION. The relationship $ny \sin\theta = n'y' \sin\theta'$, where n,n' are indices of refraction, y,y' are distances from optical axis, and θ,θ' are angles light rays make with the optical axis. A failure of an optical surface to satisfy the sine condition is a measure of the **coma** of the surface.

ABBE THEORY OF THE RESOLUTION OF A MICROSCOPE. A theory relating the **resolution** of the instrument to the wavelength of the light and the **aperture** of the instrument.

ABC. Abbreviation for automatic brightness control; automatic bass control.

ABEL EQUATION. When a particle falls on a smooth curve, $s = s(z)$ in a vertical plane from $z = z_0$ to $z = z$, the time of descent is

$$t(z_0) = \frac{1}{\sqrt{2g}} \int_0^z \frac{s'(z)}{\sqrt{z_0 - z}}\, dz$$

where g is the acceleration of gravity. Abel's problem is to find a curve for which the time of descent is a given function of z, $t(z_0) = f(z_0)$. The result is

$$f(z_0) = \int_0^{z_0} \frac{\phi(z)}{\sqrt{z_0 - z}}\, dz$$

where

$$\phi(z) = -\frac{s'(z)}{\sqrt{2g}} > 0.$$

It is a **Volterra integral equation** of the first kind.

ABELIAN GROUP. A commutative group, thus $AB = BA$ where A, B are any two elements contained in it. A simple example is the **cyclic group** of order n.

ABERRATION, ANGLE OF. See **aberration of light, Bradley.**

ABERRATION(S), FIVE GEOMETRICAL. (1) **Spherical Aberration.** (2) **Coma.** (3) **Astigmatism.** (4) **Curvature of Field.** (5) **Distortion.** Also called the "third-order" aberrations and first comprehensively analysed by Von Seidel.

ABERRATION, LEAST CIRCLE OF. The area of minimum cross section of the rays from an optical system with **spherical aberration.**

ABERRATION OF LIGHT (BRADLEY). The apparent displacement of a star due to the motion of the earth in its orbit. Maximum value about 20.5 seconds of arc when the star is viewed normal to the velocity of the earth. Distinct from **parallax.**

ABERRATION, OPTICAL. The failure of an optical system to form an image of a point as a point, of a straight line as a straight line, and of an angle as an equal angle. (See **spherical aberration, astigmatism, coma, curvature of field, distortion** (of the image), and **chromatic aberration.**)

ABNEY COLORIMETER. See **colorimeter, Abney.**

ABNEY EFFECT. A shift in **hue** which is the result of a variation in **purity** and, therefore, in **saturation.** The Abney effect may be represented by **chromaticity loci,** of specified **luminance,** with the **hue** and **brightness** constant, when **purity** and, therefore, **saturation** are varied. It is a relationship, of psychophysical nature, between psychophysical specifications and color sensation attributes.

ABNEY MOUNTING. A method for mounting a **grating,** plateholder and **slit** on a **Rowland circle** and moving only the slit to observe different parts of the spectrum.

ABNORMAL GLOW. In a **glow-discharge** device, the flow of current equal or greater than the magnitude which causes the cathode to be completely covered with glow.

ABNORMAL REFLECTIONS. Ionospheric reflections of radiowaves at frequencies higher than the **critical frequency** of the layer. Sometimes referred to as sporadic reflections.

ABRAHAM THEORY OF THE ELECTRON. Model of the electron as a rigid spherical ball of charge, the mass being regarded as of purely electromagnetic origin (1903). Yields an incorrect expression for the variation of mass with velocity, and abandoned when the predictions of special relativity theory (see **relativity theory, special**) were confirmed.

ABSCISSA. The horizontal coordinate of a point in a two-dimensional system, commonly rectangular Cartesian, and usually designated by x. Together with the **ordinate** it locates the position of the point in a plane.

ABSOLUTE FUTURE OF AN EVENT. All events which could be reached by a signal emitted at the event and moving with velocity less than or equal to that of light in a vacuum.

ABSOLUTE HUMIDITY. See **humidity, absolute.**

ABSOLUTE PAST OF AN EVENT. All events from which a signal, moving with velocity less than or equal to that of light in a vacuum, could be emitted to reach the event in question.

ABSOLUTE SPACE-TIME. A fundamental concept underlying **Newtonian mechanics** is that there exists a preferred reference system to which all measurements should be referred. This is known as absolute space-time. The assumption of such a system is replaced in **relativistic mechanics** by the principle of equivalence. (See **equivalence, principle of.**)

ABSOLUTE TEMPERATURE SCALE. See **temperature scale, absolute.**

ABSOLUTE UNITS. Any set of units defined in terms of fundamental (arbitrary) units of mass, length, and time by connecting physical equations. Compare **international units.** (**Cgs electrostatic, cgs electromagnetic,** and **MKSA units** are absolute units.)

ABSOLUTE ZERO. The temperature at which a system would undergo a reversible **isothermal** process without transfer of heat. This is the temperature at which the volume

of an ideal gas would become zero. The value calculated from the limiting value of the coefficient of expansion of various real gases is $-273.16°C$.

ABSORBANCE. The common logarithm of the **absorptance.** It may be applied to the total radiation, the visible radiation or to a particular part of the spectrum (spectral absorbance).

ABSORBANCY. The common logarithm of the reciprocal of the **transmittancy.**

ABSORBED DOSE. The International Commission on Radiological Units (July, 1953) in its revised recommendations, established the "absorbed dose of any ionizing radiation as the amount of energy imparted to matter by ionizing particles per unit mass of irradiated material at the place of interest. It is expressed in **rads.**"

ABSORBED DOSE, DETERMINATION OF. The International Commission on Radiological Units recommended (July, 1953): "Since the calorimetric methods of determining absorbed doses are not usually practicable, ionization methods are generally employed. The quantity which must be measured is the ionization produced in a gas by the same flow of corpuscular radiation as exists in the material under consideration. The energy, E_m, imparted to unit mass of the material is then essentially related to the ionization per unit mass of gas, J_m, by the equation

$$E_m = WsJ_m$$

where W is the average energy expended by the ionizing particles per ion-pair formed in the gas, and s is the ratio of the mass stopping power of the material to that of the gas. Since the calculation of the absorbed dose from measurements of ionization requires a knowledge of the parameters W and s as well as variables characterizing the radiation and the irradiated material, it is recommended that tables of the best available data be prepared and held under continual review."

ABSORBED DOSE, INTEGRAL. The integration of the energy absorbed throughout a given region of interest. The unit is the **gram-rad.**

ABSORBENT. A substance, material, or solution able to **imbibe,** or "attract into its mass," or trap liquids or gases, commonly to remove them from a given medium or region.

ABSORBER. In general, a medium, substance or functional part that takes up matter or energy. Specifically a body of material introduced between a source of radiation and a detector to (1) determine the energy or nature of the radiation; (2) to shield the detector from the radiation; or (3) to transmit selectively one or more components of the radiation, so that the radiation undergoes a change in its energy spectrum. Such an absorber may function through a combination of processes of true **absorption, scattering** and **slowing-down.**

ABSORPTANCE. The ratio of the **radiant flux** absorbed in a body of material to the radiant flux incident upon it. Commonly, the material is in the form of a parallel-sided plate and the radiation in the form of a parallel beam incident normally on the surface of the plate. Properly, transmission measurements should be corrected for reflection and scattering losses to determine the absorptance. The absorptance may be measured for any radiation, for visible light (optical absorptance) or as a function of the wavelength of the radiation (spectral absorptance).

ABSORPTIOMETER. A device equipped with a simple dispersing system or with filters by which a determination may be made of the concentration of substances by their absorption of nearly monochromatic radiation at a selected wavelength. Note that this is the third meaning given under **colorimeter.**

ABSORPTION. (1) The process whereby the total number of particles emerging from a body of matter is reduced relative to the number entering, as a result of interaction of the particles with the body. (2) The process whereby the kinetic energy of a particle is reduced while traversing a body of matter. This loss of kinetic energy of corpuscular radiation is also referred to as moderation, slowing, or stopping. (3) The process whereby some or all of the energy of **sound waves** or **electromagnetic radiations** is transferred to the substance on which they are incident or which they traverse. (4) The process of "attraction into the mass" of one substance by another so that the absorbed substance disappears physically.

ABSORPTION BAND. A region of the **absorption spectrum** in which the **absorptivity** passes through a maximum or inflection.

ABSORPTION CELL. A glass vessel used to hold liquids for the determination of their **absorption spectra.**

ABSORPTION COEFFICIENT. (1) For the absorption of one substance or phase in another, as in the absorption of a gas in a liquid, the absorption coefficient is the volume of gas dissolved by a specified volume of solvent; thus a widely-used coefficient is the quantity α in the expression $\alpha = V_0/Vp$, where V_0 is the volume of gas reduced to standard conditions, V is the volume of liquid and p is the partial pressure of the gas. (2) In the case of sound, the absorption coefficient (which is also called the acoustical absorptivity) is defined as the fraction of the incident **sound energy** absorbed by a surface or medium, the surface being considered part of an infinite area. (3) In the most general use of the term absorption coefficient, applied to electromagnetic radiation and atomic and sub-atomic particles, it is a measure of the rate of decrease in intensity of a beam of photons or particles in its passage through a particular substance. One complication in the statement of the absorption coefficient arises from the cause of the decrease in intensity. When light, x-rays, or other electromagnetic radiation enters a body of matter, it experiences in general two types of attenuation. Part of it is subjected to **scattering,** being reflected in all directions, while another portion is absorbed by being converted into other forms of energy. The scattered radiation may still be effective in the same ways as the original, but the absorbed portion ceases to exist as radiation or is re-emitted as secondary radiation. Strictly therefore, we have to distinguish the true absorption coefficient from the **scattering coefficient;** but for practical purposes it is sometimes convenient to add them together as the total attenuation or **extinction coefficient.**

Accurate measurements upon radiation which has traversed various thicknesses of matter has established that any infinitely-thin layer perpendicular to the direction of propagation cuts down the flux density by a fraction of its value proportional to the thickness of the layer, whence by integration (when permissible) the flux density after having penetrated the medium to a distance x is

$$I = I_0 e^{-ax};$$

in which I_0 is the flux density just after entrance into the medium (i.e. for $x = 0$). (See the **Bouguer law.**) For true absorption, the constant a is the absorption coefficient. For scattering, which obeys the same law, a is the scattering coefficient. And for the total attenuation, including both, it is the **extinction coefficient,** which is the sum of the absorption and the scattering coefficients.

The absorption coefficient may be computed for total radiation which enters the absorbing material, for the visible luminous radiation or as a function of wavelength, being in that case, the **spectral absorption coefficient.** The absorption coefficient divided by the density of the absorbing medium is called the mass absorption coefficient. (See **absorption coefficient, mass** and other qualified terms.)

ABSORPTION COEFFICIENT, AMPLITUDE. The absolute value of the natural logarithm of the ratio of the peak sound pressure (see **sound pressure, peak**) or particle velocity (see **velocity, particle**) at two points (along the path of the sound beam) a unit distance apart. It is usually measured in nepers/cm. In a plane wave, if ξ_1 is the maximum particle velocity at x_1 and ξ_2 is that at x_2, measured in the direction of propagation of the wave, the amplitude absorption coefficient α is given by

$$\alpha = \frac{1}{x_2 - x_1} \ln \frac{\xi_1}{\xi_2}.$$

ABSORPTION COEFFICIENT, ATOMIC. The atomic absorption coefficient of an element is the fractional decrease in intensity, per number of atoms per unit area, it is equal to the linear absorption coefficient (see **absorption coefficient, linear**) divided by the number of atoms per unit volume, or to the mass absorption coefficient (see **absorption coefficient, mass**) divided by the number of atoms per unit mass. If the medium consists of only one nuclide, the atomic absorption coefficient μ_a is equivalent to the total **cross section** for the radiation in question.

ABSORPTION COEFFICIENT, LINEAR. The linear **absorption coefficient** μ_l is the fractional decrease in intensity per unit distance

traversed, or $\mu_l = -dI/Idx$, where I is the intensity of the beam and x is the distance traversed.

ABSORPTION COEFFICIENT, MASS. The mass **absorption coefficient** μ_m is the fractional decrease in intensity per unit surface density. For a substance of density ρ, μ_m is equal to μ_e/ρ, and hence is independent of the density.

ABSORPTION CURVE. The graphical relationship between thickness of absorbing material and intensity of transmitted radiation.

ABSORPTION DISCONTINUITY. A discontinuity appearing in the **absorption coefficient** of a substance for a particular type of radiation when expressed as a function of the energy (or frequency or wavelength) of this radiation. An absorption discontinuity is often associated with anomalies in other variables such as the **refractive index.**

ABSORPTION EDGE. The wavelength corresponding to an abrupt discontinuity in the intensity of an absorption spectrum, notably an x-ray absorption spectrum, which gives the appearance of a sharp edge in the photograph of such a spectrum.

ABSORPTION, EXPONENTIAL. The removal of photons or particles from a beam, as it travels through matter, according to the exponential relationship:

$$I = I_0 e^{-\mu x}$$

where I is the intensity of the beam after traveling through a thickness of matter x, I_0 is the initial intensity of the beam, μ is the appropriate absorption coefficient, and e is the natural logarithmic base.

ABSORPTION FACTOR. In any absorbing system, especially in the case of absorption of **radiation,** the ratio of the total unabsorbed radiation to the total incident radiation, or to the total radiation transmitted in the absence of the absorbing substance. (Cf. **absorptivity.**)

ABSORPTION INDEX. In traversing perpendicularly a thin layer of absorbing material of thickness d, the amplitude of vibration of light of wavelength λ decreases in the ratio

$$1 : \epsilon^{-2\pi\kappa\frac{d}{\lambda}}$$

where κ is the absorption index. In consequence, the ratio of the intensities of the emerging and incident light is given by

$$I_1/I_0 = e^{-4\pi\kappa\frac{d}{\lambda}}.$$

For an absorbing layer of thickness λ this ratio becomes

$$I_1/I_0 = e^{-4\pi\kappa}.$$

The **absorption coefficient** "a" is given by

$$I_1/I_0 = e^{-ad}$$

hence

$$a = 4\pi\kappa/\lambda.$$

ABSORPTION LIMIT. See **absorption discontinuity.**

ABSORPTION LOSS, ACOUSTIC. That part of the **transmission loss** due to the dissipation or conversion of sound energy into other forms of energy (e.g., heat), either within the medium or attendant upon a reflection.

ABSORPTION MESH. A **filter element** used in a **waveguide** system to absorb spurious components of electromagnetic energy.

ABSORPTION MODULATION. See **modulation, absorption.**

ABSORPTION, SELECTIVE. **Absorption** which varies in amount with wavelength.

ABSORPTION SPECTRUM. See **spectrum, absorption.**

ABSORPTION TRAP. See **trap.**

ABSORPTIVE POWER, OPTICAL. The same as **absorptivity.**

ABSORPTIVITY, OPTICAL. The **transmissivity** subtracted from unity.

ABUNDANCE RATIO. The proportions of the various **isotopes** making up a particular specimen of an **element.**

ABVOLT. The **cgs electromagnetic unit** of **potential difference** and **electromotive** force. It is the potential difference that must exist between two points in order that one erg of work be done when one abcoulomb of charge is moved from one point to the other. One abvolt is 10^{-8} volt.

A-C. See **alternating current.**

A-C BRIDGES. See **bridges.**

A-C–D-C RECEIVERS. Radio **receivers** designed without **transformers** in the **power supply** so they may be connected to either **alternating-current** or **direct-current circuits.** The heaters or filaments of the various **tubes**

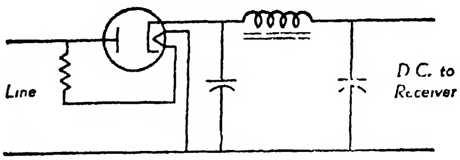


Plate supply of a-c–d-c receiver

are connected in series with the proper series or parallel resistors to adjust the current to the correct value. The d-c voltage for the plates is obtained from a rectifier-filter circuit connected directly to the line. A simple half-wave type is shown. Such supplies prevent the use of a direct ground since the 110-volt line has one side grounded and there is always the possibility of connecting the receiver plug so it would short the line if the receiver were grounded.

A-C MAGNETIC BIASING. See **magnetic biasing, a-c.**

A-C PLATE RESISTANCE. See **dynamic plate resistance.**

ACCELERATING CHAMBER. Any evacuated envelope in which charged particles are accelerated.

ACCELERATING ELECTRODE (OF AN ELECTRON-BEAM TUBE). See **electrode, accelerating (of an electron-beam tube).**

ACCELERATING TUBE. An **accelerating chamber** of general tubular construction, either toroidal as in a **betatron** or cylindrical with a large length-to-diameter ratio as in an **electrostatic accelerator** or **linear** electron **accelerator.** It may be sealed off or continuously evacuated.

ACCELERATION. The time rate of change of velocity. Like velocity, acceleration is a vector quantity, requiring the specification of both a magnitude and a direction. The defining equation is

$$\mathbf{a} = \frac{d\mathbf{v}}{dt}$$

where $\mathbf{v}$ is the instantaneous velocity and t the time. Acceleration may be indicative of a change in speed, of a change in the direction of a velocity of constant magnitude, or of a combination of the two. The quantity just defined is strictly speaking the instantaneous acceleration. (Cf. **acceleration, average.**)

ACCELERATION, ANGULAR. Angular acceleration is the time rate of change of the angular velocity, expressed by the vector derivative $d\omega/dt$. Only in case the direction of the axis remains unchanged can the angular velocity and angular acceleration be treated as scalars. The effect of torque applied to a body free to rotate about an axis is to give it angular acceleration, and the opposition offered by the body to this process gives rise to the concept of **moment of inertia.**

ACCELERATION, AVERAGE. If the instantaneous velocity of a particle is $\mathbf{v}_1$ at a given instant and $\mathbf{v}_2$ at a time Δt later, the average acceleration during the time Δt is defined as:

$$\mathbf{a}_{av} = \frac{\mathbf{v}_2 - \mathbf{v}_1}{\Delta t}$$

ACCELERATION, INSTANTANEOUS. See **acceleration.**

ACCELERATION OF GRAVITY. (1) The ratio of the weight of a material particle to its mass at any specific point in an approximately uniform gravitational **field.** This is the **acceleration** with which a body would fall in the absence of all other disturbing forces, such as those due to friction.

(2) Specifically, the acceleration with which a body falls *in vacuo* at a given point on or near a given point on the earth's surface. This acceleration, frequently denoted by g, varies by less than one percent over the entire surface of the earth. Its "average value" has been defined by the International Commission of Weights and Measures as 9.80665 M/S² or 32.174 ft/S². Its value at the poles is 9.8321 M/S² and at the equator 9.7799 M/S².

ACCELERATION, UNITS OF. The dimensional expression for acceleration is $\frac{L}{T^2}$. This becomes:

in the cgs system: $\frac{\text{cm}}{\text{S}^2}$

in the lb ft sec or English system: $\frac{\text{ft}}{\text{S}^2}$

in the MKS system: $\frac{\text{M}}{\text{S}^2}$.

ACCELERATOR, CONSTANT - POTENTIAL. A device in which a d-c potential is applied to an **accelerating tube** to produce high-energy ions or electrons.

ACCELEROMETER. (1) An instrument for determining the **acceleration** of the system with which it moves. (2) A **transducer** which gives an indication, usually in the form of a voltage proportional to the acceleration to which it is subjected.

ACCEPTOR (IN A SEMICONDUCTOR). See **acceptor impurity.**

ACCEPTOR ENERGY LEVEL. An **acceptor impurity** atom in a crystal is equivalent to an excess negative charge, since its **atomic core** is insufficiently charged to neutralize its share of the **covalent bonding** electrons. Consequently, it can attract a positive charge, such as a **hole** in the electron distribution, forming bound states which lie just above the top of the **valence band.** The promotion of an electron to one of these levels frees a hole for conduction, as in a p-type semiconductor (see **semiconductor, p-type**).

ACCEPTOR IMPURITY. An **impurity,** in a **semiconductor,** which may induce **hole** conduction. Such an impurity is capable of accepting an electron from the **valence band,** forming an **acceptor energy level.**

ACCESS TIME. (1) The time interval, characteristic of a memory or storage device, between the instant at which **information** is requested of the **memory** and the instant at which this information begins to be available in useful form. (2) The time interval between the instant at which information is available for storage and the instant at which it is effectively stored.

ACCESSIBLE TERMINAL. A **network node** that is available for external connections.

ACCIDENTAL DEGENERACY. See **Fermi resonance.**

ACCOMMODATION COEFFICIENT. A quantity defined by the equation:

$$a = \frac{T_3 - T_1}{T_2 - T_1}$$

where T_1 is the temperature of gas molecules striking a surface which is at temperature T_2, and T_3 is the temperature of the gas molecules as they leave the surface, a is the accommodation coefficient. It is, therefore, a measure of the extent to which the gas molecules leaving the surface are in thermal equilibrium with it.

ACCOMMODATION, OCULAR. Accommodation of the eye for objects at different distances is brought about by changes in the tension of the ciliary muscles which control the shape of the **crystalline lens.**

ACCUMULATION COEFFICIENT. A term sometimes used specifically to denote the rate of increase in the concentration of **adsorbed** molecules upon a surface, in relation to the concentration of that molecular species in the phase in contact with the surface.

ACCUMULATION POINT. One of a **set** such that any neighborhood of this point, no matter how small, contains a member of the set. All the points of a set which is everywhere dense are accumulation points.

ACCUMULATOR. A device which stores a number and, upon reception of a new number, adds it to the previous contents and stores the sum. An accumulator may have properties such as shifting, sensing signs, clearing, complementing, etc.

ACCURACY. The quality of correctness or freedom from error. Distinguished from precision as in the examples: (a) ". . . this procedure measures the precision (reproducibility) of the test, not its accuracy (closeness to the true value)." (b) A four-place table correctly computed is more accurate but less precise than a six-place table containing errors. (c) The accuracy of an instrument is a number or quantity which defines its limit of error. (See also **precision.**) The actual error in measurement can seldom be determined, but its magnitude may usually be estimated.

ACCURACY IN MEASUREMENT. The degree of correctness with which a method of measuring yields the "true" value of a measured quantity. It is usually expressed in terms of error, the units being those of the measured quantity or the ratio (or percent) of the error to the full scale value or to the actual value.

ACHROMAT. A **compound lens** corrected so as to have the same focal length for two or

more different wavelengths. Commonly the **F-** and **C-lines** are the chosen wavelengths.

ACHROMATIC. (1) Free from **hue** (see **achromatic color**). (2) Transmitting light without showing its constituent colors, or separating it into them.

ACHROMATIC COLOR. Devoid of **hue.** Such a color is often called grey.

ACHROMATIC COMBINATION. If reversed crown and flint prisms are made of such angle that the **angles of dispersion** between any two different wavelengths of light are alike but reversed in direction, then these two colors will not be separated and all colors lying between them will be separated little if any from each other. By using three kinds of glass it is possible to bring three colors together. When the dispersions balance, the **deviations** will in general not balance. This same principle is used in making achromatic lenses. Achromatic prisms have a maximum of deviation and a minimum of dispersion while an **Amici prism** disperses the light with a minimum of deviation.

ACHROMATIC LOCUS. Chromaticities which may be acceptable reference standards under circumstances of common occurrence are represented in a **chromaticity diagram** by points in a region which may be called the "achromatic locus." Any point within the achromatic locus, chosen as a reference point, may be called an **"achromatic point."** Such points have also been called "white points." However, the term "white point" is best used to specify the intersection of the various achromatic loci obtained under different conditions of adaptation.

ACHROMATIC POINT. The point on a **chromaticity diagram** that represents an **achromatic stimulus.**

ACHROMATIC STIMULUS. (1) A visual stimulus that is capable of exciting a color sensation of no **hue.** (2) In practice, an arbitrarily-chosen **chromaticity,** such as that of the prevailing illumination.

ACHROMATISM. The state or quality of being achromatic.

ACROMATISM, D-G. See **D-G acromatism.**

ACOUSTIC. The word "acoustic," when used as a qualifying term, means containing, producing, arising from, actuated by, or carrying sound, or designed to carry sound and capable of doing so.

ACOUSTIC BRANCH. See **acoustic mode.**

ACOUSTIC CAPACITANCE, SPECIFIC. See **capacitance, specific acoustic.**

ACOUSTIC CENTER, EFFECTIVE. An acoustic generator, the point from which the spherically divergent sound waves, observable at remote points, appear to diverge.

ACOUSTIC COMPENSATOR. A device for adjusting acoustical path lengths for matching purposes in binaural listening.

ACOUSTIC COMPLIANCE. See **compliance, acoustic.**

ACOUSTIC DEPTH FINDING, ECHO METHOD. In determining ocean depths, a sound pulse is emitted from a loudspeaker mounted on the ship's hull and directed downward. The pulse is reflected from the ocean bottom and received by a hull-mounted microphone. The returned signal is plotted as the ordinate on a recorder, with time as the abscissa. The mechanism records every few seconds, so that a virtually continuous trace of depth vs. time, or depth vs. distance traveled by ship, is recorded.

ACOUSTIC DETECTOR, BROCA TUBE. An early type of pressure sensitive acoustic receiver, consisting of a sphere of rubber or sheet metal mounted at the end of a listening tube.

ACOUSTIC DETECTOR, DISPLACEMENT. Any acoustic receiver that measures directly the displacement of the medium.

ACOUSTIC DETECTOR, PRESSURE. Any acoustic receiver that is operated primarily by the excess pressure produced by the sound in the medium in which the detector is placed.

ACOUSTIC DISPERSION. See **dispersion, acoustic.**

ACOUSTIC FEEDBACK. The returning of a fraction of the output of an acoustical device to the input of the same device.

ACOUSTIC FILTER. See **filter, wave.**

ACOUSTIC GENERATOR. See **generator, acoustic.**

ACOUSTIC HORN. See **horn, acoustic.**

ACOUSTIC IMPEDANCE. See **impedance, acoustic.**

ACOUSTIC IMPEDANCE, SPECIFIC. See **impedance, specific acoustic.**

ACOUSTIC INERTANCE. See **mass, acoustic.**

ACOUSTIC INTERFEROMETER. See **interferometer, acoustic.**

ACOUSTIC MASS. See **mass, acoustic.**

ACOUSTIC MODE. A type of **thermal vibration** of a crystal lattice (see **space lattice**) which, in the limit of long wavelengths, is equivalent to an acoustic wave travelling with nearly constant velocity as if through an elastic **continuum.** At high frequencies, approaching the **Debye frequency,** the phase velocity of the acoustic modes tends to decrease, owing to dispersion

ACOUSTIC PICKUP (SOUND BOX). See **pickup, acoustic (sound box).**

ACOUSTIC RADIATING ELEMENT. See **radiating element, acoustic.**

ACOUSTIC RADIOMETER. See **radiometer, acoustic.**

ACOUSTIC REACTANCE. See **reactance, acoustic.**

ACOUSTIC REACTANCE, SPECIFIC. See **reactance, specific acoustic.**

ACOUSTIC REFRACTION. See **refraction, acoustic.**

ACOUSTIC RESISTANCE. See **resistance, acoustic.**

ACOUSTIC RESISTANCE, SPECIFIC. See **resistance, specific acoustic.**

ACOUSTIC SCATTERING. See **scattering, acoustic.**

ACOUSTIC STIFFNESS. See **stiffness, acoustic.**

ACOUSTIC TRANSMISSION SYSTEM. See **transmission system, acoustic.**

ACOUSTIC UNITS. In acoustics, the centimeter-gram-second (cgs) system of units has been and is at present predominantly used, but some practical units such as English and metric system units of length are also being used, and the watt is commonly being employed for designating acoustic power. In recent years there has been a trend toward adoption of the rationalized meter-kilogram-second system of units in many fields of science and engineering Therefore the Mks units are included in conversion table on page 10, even though they have not been employed in acoustics.

ACOUSTICAL. When used as a qualifying term denotes related, pertaining to, or associated with sound, but not having its properties or characteristics

ACOUSTICAL ABSORPTION COEFFICIENT. See **sound absorption coefficient.**

ACOUSTICAL ABSORPTIVITY. See **sound-absorption coefficient.**

ACOUSTICAL ADJUSTMENT OF ROOMS. The modification of the average **sound absorption coefficient** of a room by the introduction of acoustical materials of greater or lesser absorptivity.

ACOUSTICAL ATTENUATION CONSTANT. (See also **absorption coefficient, amplitude.**) The acoustical attenuation constant is the real part of the acoustical propagation constant The commonly used unit is the **neper** per section or per unit distance. In the case of a symmetrical structure, the real parts of both the **transfer constant** and the **acoustical propagation constant** are identical, and have been called the "wavelength constant"

ACOUSTICAL ELEMENTS. The parameters, analogous to electrical elements, that characterize the action of each component of an acoustical system

ACOUSTICAL MIRAGE. The distortion of a **wave front** by a strong temperature gradient so that part of the wave front overlaps another, creating the illusion of two sound sources although only a single source exists.

ACOUSTICAL OHM. An acoustic resistance, reactance, or impedance has a magnitude of one acoustical ohm when a sound pressure of 1 **microbar** produces a volume velocity (see **velocity, volume**) of 1 **cubic centimeter per second**

ACOUSTICAL PHASE CONSTANT. The acoustical phase constant is the imaginary part of the **acoustical propagation constant.** The commonly used unit is the radian per section or per unit distance. Note: In the case of a symmetrical structure, the imaginary parts of both the **transfer constant** and the **acoustical propagation constant** are identical, and have been called the "wavelength constant."

ACOUSTICAL PRINCIPLE OF SIMILARITY. For any acoustical system involving **diffraction** phenomena, it is possible to construct a new system on a different scale which will perform in similar fashion, provided that the wavelength of the sound is altered in the same ratio as the linear dimensions of the original system.

ACOUSTICAL PROPAGATION CONSTANT. Of a uniform system or of a section of a system of recurrent structures, the natural logarithm of the complex ratio of the steady-state particle velocities (see **velocity, particle**), **volume velocities**, or pressures at two points separated by unit distance in the uniform system (assumed to be of infinite length), or at two successive corresponding points in the system of recurrent structures (assumed to be of infinite length). The ratio is determined by dividing the value at the point nearer the transmitting end by the corresponding value at the more remote point.

Conversion of Present Acoustical Units into Mks Units

Quantity	Dimension	Present Unit	Mks Unit	Conversion Factor *
Sound velocity (particle velocity)	LT^{-1}	cm per second	meter per second	10^{-2}
Volume velocity	L^3T^{-1}	cubic cm per second	cubic meter per second	10^{-6}
Sound energy	ML^2T^{-2}	erg	joule	10^{-7}
Force	MLT^{-2}	dyne	newton	10^{-5}
Sound pressure (sound-energy density)	$ML^{-1}T^{-2}$	microbar	newton per square meter	10^{-1}
Sound-energy flux (sound power of source)	ML^2T^{-3}	erg per second	watt	10^{-7}
Sound intensity (specific sound-energy flux)	MT^{-3}	erg per second per square cm watt per square cm	watt per square meter	10^{-3} 10^4
Acoustic impedance (resistance, reactance)	$ML^{-4}T^{-1}$	acoustical ohm	Mks acoustical ohm †	10^5
Specific acoustic impedance	$ML^{-2}T^{-1}$	acoustical ohm × square cm	Mks acoustical ohm † × square meter	10
Mechanical impedance (resistance, reactance)	MT^{-1}	mechanical ohm	Mks mechanical ohm †	10^{-3}

* Multiply the magnitude expressed in present units by the tabulated conversion factor to obtain magnitude in mks units.

† Mks acoustical ohm and mks mechanical ohm are proposed terms.

ACOUSTICAL REFLECTIVITY. See **sound-reflection coefficient.**

ACOUSTICAL TRANSMITTIVITY. See **sound-transmission coefficient.**

ACOUSTICS. In the broader sense, acoustics is the physics of sound, treated in all its aspects. Commonly, however, the term is restricted to a study of the transmission of sound through various media or in various enclosures or conduits, including the effects of **reflection, refraction, interference, diffraction,** and **absorption.**

The investigation of such problems as the passage of sound through simple tubes, or tubes having branches, or through cavities of various shapes, such as musical instruments or resonators, reveal certain remarkable analogies to the theory of a-c circuits. Thus one encounters the property known as acoustic impedance; with its components, acoustic resistance and acoustic reactance, the latter being dependent upon the acoustic inertance (analogous to inductance) and acoustic compliance (sometimes called acoustic capacitance). These correspond to analogous properties of a-c circuits, in which the electric impulses may be compared to acoustic waves with electricity as the medium The acoustic resistance, inertance, and compliance depend, respectively, upon the viscosity, the density, and the elasticity of the medium (See **impedance, acoustic; mass, acoustic,** etc. See also entries under **sound.**)

ACTINIDE SERIES. A term derived by analogy to the **lanthanide series** to denote elements of atomic number 89–103 inclusive. Members of this series include the known elements actinium, thorium, protactinium, uranium, neptunium, plutonium, americium, curium, berkelium, californium, element #99, element #100 and element #101. It is believed that the elements #102 and #103 will, when discovered, probably belong to this series. The justification for this grouping is found in the existence in the higher elements of (III) oxidation states similar to actinium, and (IV) oxidation states similar to thorium. Certain similarities also exist between the atomic spectra and magnetic properties in the two series.

The names einsteinium, fermium and mendelevium have been proposed for elements #99, #100 and #101.

ACTINIUM. Radioactive element. Symbol Ac. Atomic number 89.

ACTINOMETER. An instrument which measures the **intensity** of photochemically active radiation, by determining the **fluorescence** of a screen or the extent of a chemical decomposition reaction initiated by the incident radiation.

ACTINOMETRY. The determination of the photochemical intensity of light.

ACTION. The action of a dynamical system is the space integral of the total **momentum** of the system. Specifically, if $\mathbf{r}_j$ is the position vector of the jth particle of the system and m_j is the mass, the action for the path going from P_1 to P_2 is

$$\int_{P_1}^{P_2} \Sigma m_j \dot{\mathbf{r}}_j \cdot d\mathbf{r}_j\ ,$$

where the integral is taken along the actual path from P_1 to P_2. The integral can be shown to reduce to the form

$$2\int_{t_1}^{t} E_K dt$$

where E_K is the total kinetic energy of the system and t_1 and t_2 are the times at which the system is in positions P_1 and P_2 respectively. (Cf. **least action (principle of).**)

ACTION AT A DISTANCE. Theory of the interaction between charged particles in which the electromagnetic fields do not appear explicitly. In particular the Wheeler-Feynman theory, in which **radiation damping** appears when a particle is surrounded by a complete absorber of radiation. Thus on the one hand radiation damping arises as a consequence of statistical theory, while on the other the equations of motion of a classical charged particle are those of the **Dirac classical electron theory.**

ACTION, PRINCIPLE OF LEAST. See **least action, principle of.**

ACTION TIME, VISUAL. The period of visual stimulation necessary to permit a visual sensation to attain maximum strength.

ACTION VARIABLE. If one of the momenta of a classical dynamical system yields a closed curve when graphed against the conjugate coordinate, the area contained within this curve

is the action variable corresponding to this degree of freedom Usually denoted by J

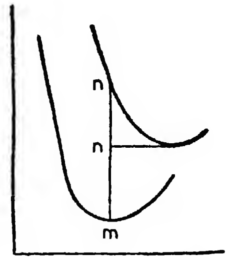
ACTIVATION. (1) In nuclear physics, the process of inducing **radioactivity** through neutron bombardment or by other types of radiation (see **cross section, activation**). (2) In electron-tube technology, the process by which the **cathode** is treated in order that maximum **emission** may occur (3) The transfer of a sufficient quantity of energy to an atomic system to raise it to an excited state in which it can participate in a process not possible when the system is in its ground state (See **activation energy.**)

ACTIVATION ANALYSIS. A method of analysis by means of **isotopes** in which a small quantity of an element that is difficult to determine is exposed to activating particles (e g , **deuterons** in a cyclotron or **neutrons** in a nuclear reactor) One or more of the stable isotopes of the element are thus converted to **radioisotopes** which can be detected by their characteristic radiations and half-lives By treating similarly a comparison sample containing a known proportion of the given element the analysis can be made quantitative

ACTIVATION ENERGY. The excess energy over the **ground state** which must be acquired by an atomic system in order that a particular process may occur Examples are the energy needed by a molecule to take part in a chemical reaction, by an electron to reach the **conduction band** in a **semiconductor**, by a **lattice defect** to move to a neighboring site

ACTIVATION ENERGY FOR LIQUID FLOW. If a liquid is regarded as an imperfect solid, the yielding to an applied shear stress takes place at a rate that depends on the frequency with which molecules leave their positions in the imperfect **crystal lattice.** The variation of this frequency with temperature is described by the energy required for an interchange of a molecule between the lattice and the free volume in the liquid If this activation energy is linearly dependent on temperature at constant pressure, the slope of the $\log_e \eta$ $1/kT$ plot gives the activation energy at low temperatures

ACTIVATION ENERGY, RELATION BETWEEN THERMAL AND OPTICAL. For a process such as the emission of an electron from an impurity center, the thermal and optical activation energies are not usually equal. In optical emission the surrounding ions do not move (**Franck-Condon principle**). The energy required (mn) is thus larger than in thermal activation, when the surrounding ions will necessarily be in the most favorable orientation for the transition to take place (mn′).



ACTIVATOR. An impurity atom present in a solid and making possible the effects of **luminescence,** or markedly increasing their efficiency Examples are copper in zinc sulfide, and thallium in potassium chloride

ACTIVE. This word is used in nuclear physics for three special meanings (1) Fissionable (active material) (2) Radioactive (active sample) (3) The active part of a **reactor** is the core (active lattice)

ACTIVE CENTER. Atoms which by their position on a surface, such as at the apex of a peak or on the edge or corner of a crystal, share with neighboring atoms an abnormally small portion of their **electrostatic field** and, therefore have a large residual field available for **catalytic** activity or for **adsorption.**

ACTIVE DEPOSIT. In general, any radioactive material deposited on a surface Specifically, any radioactive **decay product** deposited on a surface in contact with a radioactive gas, especially the gases radon, actinon and thoron

ACTIVE LINES. In television the number of lines which are actually used to display picture information

ACTIVE MASS. Mass per unit volume, usually expressed in moles per liter (a concentration factor)

ACTIVE PRODUCT. A radioactive **decay product** of a **radionuclide.**

ACTIVE TRANSDUCER. See **transducer, active.**

ACTIVITY. (1) **Radioactivity.** (2) The intensity or strength of a radioactive source, i.e., the number of atoms disintegrating in unit time, or derivatively, the number of scintillations or other effects observed per unit time. Activity is often expressed in **curies** or **rutherfords** or **roentgens** per hour at one meter. (3) The apparent effective concentration of a substance in a reacting system. In many relationships involving concentrations, it has been found that the use of actual concentrations does not give calculated results which agree with observed results, because of the departure from ideality of real gases and solutions (due to such causes as, for example, the influence of interionic or intermolecular attraction). In such cases, instead of concentrations, activities may be used. Thus, the activity a_r of the rth component in a complex phase is defined by the relationship:

$$\mu_r - \mu_r^0 = RT \ln a_r,$$

where μ_r and μ_r^0 are the chemical potentials in the system and in some standard state at the same temperature, T (the standard state is usually defined as the pure state of the component) and where R is the gas constant. For the activity of solutions, a_r may be replaced by $x_r f_r$, where x_r is the mole fraction of component r in the solution, and f_r is the **activity coefficient**, so that the equation becomes:

$$\mu_r - \mu_r^0 = RT \ln x_r f_r$$

ACTIVITY COEFFICIENT. The ratio of **activity (definition (3))** to concentration. Thus the activity coefficient f_r of the rth component in a complex phase is defined as

$$f_r = \frac{a_r}{x_r}$$

where a_r is the activity and x_r, the concentration. It is a thermodynamic function used in expressing the **chemical potentials** of real gases and solutions, and it is a useful measure of the departure from identity of these systems.

ACTIVITY COEFFICIENT, RATIONAL. The **activity coefficient** obtained by derivation from the **Debye-Hückel theory** of electrolytes.

ACTIVITY CURVE. A graph in which the **activity (definition (2))** of a radioactive source is plotted as a function of time.

ACTIVITY OF AN ELECTROLYTE, MEAN. See **mean activity of an electrolyte.**

A.D. See **average deviation.**

ADAMANTINE COMPOUND. A compound having in its crystal structure an arrangement of atoms essentially that of diamond, in which every atom is linked to its four neighbors by **covalent bonds.** An example is zinc sulfide, but it is to be noted that the eight electrons involved in forming the four bonds are not provided equally by the zinc and sulfur atoms, the sulfur yielding its six valency electrons, and the zinc, two. This is the structure of typical **semiconductors,** e.g., silicon and germanium.

ADCOCK ANTENNA. See **antenna, adcock.**

"ADD" CIRCUIT. See **comparator.**

ADDER. A device which can form the sum of two or more numbers, or quantities, impressed upon it.

ADDER, ALGEBRAIC. An **adder** which can form an algebraic sum.

ADDITION OF VELOCITIES. The law derived from special relativity theory relating the velocities $\mathbf{v}_{AB}$, $\mathbf{v}_{BC}$, $\mathbf{v}_{CA}$ where $\mathbf{v}_{AB}$ is the velocity of A relative to B, etc. For motion in one dimension it becomes

$$v_{AC} = \frac{v_{AB} - v_{CB}}{1 - \frac{v_{AB}v_{CB}}{c^2}}$$

For relative velocities small compared with the velocity c of light in a vacuum, the law reduces to the non-relativistic vector addition law for relative velocities:

$$\mathbf{v}_{AC} = \mathbf{v}_{AB} - \mathbf{v}_{CB}.$$

ADDITIVE COLOR PROCESS. A system of color photography in which the color synthesis is obtained by the addition of colors one to another in the form of light rather than as colorants.

ADDITIVITY, PRINCIPLE OF. The properties of a solution of a strong **electrolyte** are the sum of the individual properties of its **ions.** In general, an additive property applies to a system where it is the sum of the individual properties of the constituents. The only property, however, which is truly additive is mass.

ADDITRON. A Canadian special-purpose **computer tube.**

ADDRESS. Information (usually a number) which designates a particular location in a memory or storage device.

ADF. Abbreviation for **automatic direction finder.**

ADHESION AND COHESION. In physics, the terms adhesion and cohesion designate intermolecular forces holding matter together. The tendency of matter to hold itself together or to cling to other matter is one of its most characteristic properties. Adhesion and cohesion are merely different aspects of the same phenomenon, which is apparently of the nature of an intermolecular attraction. We speak of cohesion as an interaction between adjacent parts of the same body and as acting throughout the interior of its substance, while adhesion refers to a similar interaction between the closely contiguous surfaces of adjacent bodies.

There is reason to believe that as two neutral molecules or atoms approach each other, their mutual potential energy reaches a minimum value at a certain equilibrium distance; so that work would be necessary either to push them closer or to pull them farther apart, because of forces which are probably electrical. The distribution of molecules, ions, or atoms in a solid is determined by this type of equilibrium, and the regular spacing of crystal structure and the architecture of the molecule itself are dependent upon it. Any force tending to diminish the equilibrium distance meets with the rapidly increasing reaction of compressive elasticity, while any force tending to increase it is opposed by cohesion, which increases at first and then rapidly diminishes toward zero as the point of fracture is reached.

The behavior of bodies which are aggregates of crystals or of fibers is complicated by the friction and the adhesion of the adjacent particles, so that the ultimate strength of a material is not a safe measure of its true cohesion. A filament of spun quartz may be much stronger when freshly drawn than later when crystallization replaces its initial cohesion by the adhesion between separate crystals; and yarn is not nearly so strong as the cotton or wool fiber composing it.

Adhesion increases with closeness of contact. This explains why one must bear down with a pencil to make a mark on paper, why fine dust adheres more firmly than coarse sand, and why a liquid or a gum usually sticks to a solid better than another solid does.

Cohesion in liquids is usually less, and in gases it is always much less, than in solids. Aside from the pressure in liquids due to external causes, there is presumably a very great internal or intrinsic pressure, due to intermolecular attraction, but not capable of direct measurement by means at our disposal. The clearest evidences of its existence are the work required for thermal expansion and the phenomenon of surface tension.

ADHESION TENSION. The work required to enlarge the surface between a solid and a liquid is called the adhesion energy, and it may be expressed as the adhesion tension in units of force per unit of surface.

ADHESION, WORK OF. The work of adhesion W_{AB} between two liquids A and B is the increase in free surface energy (see **surface energy, free**) on separating 1 cm^2 of **interface** AB

$$W_{AB} = \gamma_A + \gamma_B - \gamma_{AB}$$

where γ_A and γ_B are the **surface tensions** of A and B respectively against their vapors, and γ_{AB} is the **interfacial tension.** For a solid-liquid interface the work of adhesion W_{SL} is defined as the work required to separate 1 cm^2 of interface in a vacuum to give a naked solid surface

$$W_{SL} = \gamma_S + \gamma_L - \gamma_{SL}$$

where γ_S and γ_L are the surface free energies measured in a vacuum. It may be shown that

$$W_{SL} = \gamma_S - \gamma_{SV_0} + \gamma_L(1 + \cos \theta_E)$$

where γ_{SV_0} is the surface tension of the solid covered by an absorbed film of liquid in equilibrium with the vapor, and θ_E the equilibrium **contact angle.**

ADIABAT. If a thermally-isolated system moves through a series of equilibrium states, the locus of the points representing these states on a graph is called an adiabat. Thus in meteorology, an adiabat is a line on a chart showing the adiabatic **lapse rate** (wet or dry).

ADIABATIC. Occurring without change in heat content, i.e., without gain or loss of heat by the system involved.

ADIABATIC APPROXIMATION. The assumption that the electronic wave functions in a molecule or solid are distorted by the motion of the nuclei, but in such a way that their energy is a function only of the nuclear configuration at a given moment, and does not depend on the rate at which the nuclei are moving (see **Born-Oppenheimer method**).

ADIABATIC COMPRESSION. Compression without exchange of heat between the compressed system and its surroundings.

ADIABATIC DEMAGNETIZATION, COOLING BY. A technique for attaining very low temperatures, of the order of 0.01°K. A crystal of a **paramagnetic** salt is cooled down to liquid helium temperatures in a strong magnetic field. The crystal is then thermally insulated, and the field removed, the **entropy** of the system remaining constant But the entropy of the **spin system** is very small in the state of order induced by the field, so that the crystal is eventually left in a state of very low entropy, that is, low temperature. The final temperature depends on the interactions between the spins, causing splitting of the energy levels, so that it is smallest for a "magnetically dilute" substance, in which the paramagnetic ions are spaced far apart, e g, $FeNH_4(SO_4)_2 \cdot 12H_2O$

ADIABATIC ELASTICITY. A term invented by Hugoniot to express the change of elasticity of the medium which is propagating an explosion wave, assuming that the medium is discontinuous in the vicinity of the wave.

ADIABATIC EXPANSION. Expansion without gain or loss of heat from outside the substance or system.

ADIABATIC INVARIANT. A quantizable quantity, which remains unchanged under the action of a slow disturbance.

ADIABATIC PROCESSES. Changes in matter which take place without transfer of heat.

ADIABATIC PROCESSES IN THE ATMOSPHERE. When a parcel of air is moved from one position to another with respect to surrounding air, in such a manner that energy does not flow across the boundaries of the parcel, thermal changes taking place within the parcel are said to be adiabatic changes. Any process in the atmosphere occurring adiabatically is known as an adiabatic process.

ADIACTINIC. Not transmitting photochemically-active rays.

ADION. An **ion** adsorbed on a surface that is held so that it is free to move on the surface but not away from it.

ADJACENT-CHANNEL ATTENUATION. See **selectance.**

ADJACENT-CHANNEL INTERFERENCE. See **interference, adjacent-channel.**

ADJOINT. See **matrix, adjoint; operator, adjoint.**

ADJOINT EQUATION. The differential equation $L(u) = u'' + p(x)u' + q(x)u = 0$ may be frequently solved by use of an **integrating factor.** Suppose such a factor v exists so that $vL(u)dx$ is an **exact differential,** then the operator adjoint to $L(u)$ is

$$\bar{L}(v) = v'' - p(x)v' + [q(x) - p'(x)]v,$$

$$vL(u) - u\bar{L}(v) = (d/dx)[P(u, v)]$$

is the **Lagrange identity,** and

$$P = uv[u'/u - v'/v + p(x)]$$

is the **bilinear concomitant.** If the adjoint equation $\bar{L}(v) = 0$ can be solved, the original equation $L(y) = 0$ is equivalent to the first order equation $P(u, v) = C$, where C is an arbitrary constant. The latter, of course, can always be solved.

An equation identical with its adjoint is said to be **self-adjoint.** Any differential equation may be put into self-adjoint form if the appropriate factor is introduced.

These procedures are not limited to equations of second order but may be generalized for those of any order.

ADJOINT WAVE FUNCTION. In **Dirac electron theory** the row-vector $\bar{\psi} = \psi^* \rho_3$ where ψ is the wave function, the asterisk denotes **Hermitean conjugate** and ρ_3 is the **Dirac operator** γ_4

ADMITTANCE. The reciprocal of **impedance.** Thus if the impedance of a circuit element is

$$Z = R + jX, \quad |Z|^2 = R^2 + X^2,$$

its admittance is

$$Y = \frac{1}{R + jX} = \frac{R - jX}{R^2 + X^2} = \frac{R}{|Z|^2} - j\frac{X}{|Z|^2}$$

$$\equiv G + jB$$

The real part of admittance is called **conductance** (G); the imaginary part, **susceptance** (B). Note that positive reactance implies negative susceptance.

ADMITTANCE, BACKWARD TRANSFER (OR FEEDBACK ADMITTANCE). The short-circuit transfer admittance from the output electrode to the input electrode of an electron tube. (See **interelectrode transadmittance.**)

ADMITTANCE, CIRCUIT. See **admittance, driving-point.**

ADMITTANCE, COMPLEX. The admittance of a **network branch** is given by the ratio of the current through the branch to the voltage across the branch, with current and voltage expressed as complex numbers.

ADMITTANCE, DRIVING-POINT (between the jth Terminal and the Reference Terminal of an n-Terminal Network). The quotient of the complex alternating component I_j of the current flowing to the jth terminal from its external termination by the complex alternating component V_j of the voltage applied to the jth terminal with respect to the reference point when all other terminals have arbitrary external terminations. In specifying the driving-point admittance of a given pair of terminals of a network or transducer having two or more pairs of terminals, no two pairs of which contain a common terminal, all other pairs of terminals are connected to arbitrary admittances.

ADMITTANCE, ELECTRONIC. The admittance of a vacuum tube caused by the action of electron beams within the tube. (See **admittance, driving-point.**)

ADMITTANCE, FEEDBACK. See **admittance, backward transfer.**

ADMITTANCE, FORWARD TRANSFER (OR TRANSADMITTANCE). The short-circuit transfer admittance from the input electrode to the output electrode of an electron tube. (See **interelectrode transadmittance.**)

ADMITTANCE, NORMALIZED. The reciprocal of the normalized impedance. (See **impedance, normalized.**)

ADSORBATE. A substance which is adsorbed.

ADSORBENT. A substance or material which adsorbs.

ADSORPTION. A type of adhesion which takes place at the surface of a solid or a liquid in contact with another medium, resulting in an accumulation or increased concentration of molecules or other particles from that medium in the immediate vicinity of the surface

ADSORPTION, ACTIVATED. Chemisorption (**adsorption** involving forces of chemical nature) in which the activation energy is relatively high (See also **adsorption, types of.**)

ADSORPTION, APOLAR. Adsorption of nonpolar substances on nonpolar media.

ADSORPTION, DISPLACEMENT. Displacement from a surface of one adsorbed substance by another.

ADSORPTION EQUATION, GIBBS. See **Gibbs adsorption equation.**

ADSORPTION EQUILIBRIUM. Equilibrium between a substance that is adsorbed upon a surface, and the same substance in a solution or other medium that is in contact with the surface.

ADSORPTION EXPONENT. The exponential term n in the (classical) **adsorption isotherm.**

ADSORPTION, HEAT OF. When a gas or vapor is adsorbed on a solid, heat is liberated. There are two ways of expressing these heat effects: (1) Integral heat of adsorption, which is the total amount of heat, Q cal, given out when 1 g of the outgassed solid takes up m g of the gas or vapor. It is expressed as calories per g of adsorbent, for an adsorption of m g of adsorbate. (2) Differential heat of adsorption,

$$-\Delta H = M\frac{\partial\phi}{\partial m}$$

where M is the molecular weight of adsorbate. Heats of adsorption may be measured by means of a calorimeter. They may also be calculated from heats of immersion and condensation.

In the case of a liquid, the heat of adsorption of solute from solution may be determined from the thermodynamic relation:

$$\Delta H^\circ = \Delta G^\circ - T\frac{d(\Delta G^\circ)}{dT}$$

where ΔH° and ΔG° are the heat of and free energy (see **free energy (1)**) of adsorption. For dilute solutions:

$$\Delta G^\circ = -RT\ln\frac{C_{\text{solid}}}{C_{\text{solution}}} = -RT\ln\frac{\Gamma}{\gamma C_{\text{solution}}}$$

where C_{solution} is the concentration of the solute in solution, C_{solid} is the concentration of the adsorbed solute, Γ is the amount of adsorbed solute per unit area of surface, and γ is the thickness of the adsorbed film. The heat of adsorption may be also measured colorimetrically.

ADSORPTION ISOSTERE. A graph showing the variation with temperature of the pressure required to keep a predetermined quantity of gas adsorbed on a given solid surface in equilibrium with the gas.

ADSORPTION ISOTHERM. A relationship between the mass of substance adsorbed at a given temperature and the mass of adsorbent. The Freundlich or classical adsorption isotherm is of the form:

$$\frac{x}{m} = kp^{1/n}$$

in which x is the mass of gas adsorbed, m is the mass of adsorbent, p is the gas pressure, and k and n are constants for the temperature and system. In certain systems, it is necessary to express this relationship as:

$$\frac{x}{m} = k(h\gamma)^{1/n}$$

where h is the relationship of the partial pressure of the vapor to its saturation value, and γ is the surface tension. Numerous isotherm equations have been proposed in the chemical literature in the last fifty years. The Langmuir adsorption isotherm is of the form

$$\frac{x}{m} = \frac{k_1k_2p}{1 + k_1p}.$$

Brunauer, Emmett and Teller have obtained an equation which is more general than the Langmuir equation. For a critical review of the theory, see Halsey, *J. Chem. Phys.*, **17,** 758 (1949); and Hill, *J. Chem. Phys.*, **17,** 106 (1949). (See also **Gibbs adsorption equation.**)

ADSORPTION ISOTHERM, GIBBS. See **Gibbs adsorption equation.**

ADSORPTION, NEGATIVE. A phenomenon exhibited by certain solutions in which the concentration of solute is less in the surface than it is throughout the solution. This behavior is shown by solutes that increase the surface tension.

ADSORPTION, ORIENTED. State of adsorption in which the adsorbed molecules are uniformly (or partially) ordered with respect to orientation.

ADSORPTION, POLAR. Adsorption of electrically unequal amounts of ions, so that the adsorbed film has an over-all electrical charge. Also adsorption chiefly attributable to attraction between polar groups of adsorbent and adsorbate.

ADSORPTION POTENTIAL. The energy change experienced by a molecule (ion) in passing from the gas (or solution) phase to the surface of the adsorbent.

ADSORPTION SPACE. The thickness of an adsorbed layer.

ADSORPTION, SPECIFIC. (1) Preferential **adsorption** of one substance over another (2) Quantity of adsorbate held per unit area of adsorbent.

ADSORPTION, TYPES OF. The adsorption of gases (or liquids) on solids has been divided into two main classes depending on whether the adsorption is of a physical or chemical nature. The first, generally known as van der Waals adsorption, involves van der Waals or dispersion forces. This type of adsorption is accompanied by a relatively small heat of adsorption, of the order of 5 Kcal/mole or smaller and is reversible. The **adsorption isotherm** is one for which the amount adsorbed increases rather slowly with pressure. In chemisorption, forces of a chemical or valency nature are involved. This adsorption is difficult to reverse, and the heat of adsorption is as great as that found in chemical reactions

and is of the order of 20–100 Kcal/mole. This type of adsorption is usually specific. A typical example of van der Waals adsorption is the adsorption of nitrogen on charcoal at low temperatures, while an example of chemisorption is the adsorption of oxygen on tungsten.

When chemisorption does not occur readily at room temperatures but requires an activation energy of the order of 5 Kcal/mole or greater, the adsorption process is usually referred to as activated adsorption. An example of this is the adsorption of hydrogen on nickel.

ADVANCE BALL. In recording, a rounded object which rides ahead of the cutting stylus. Its function is to maintain uniformity of groove depth.

ADVANCED FIELDS. Electromagnetic field strengths, **E**, **B**, at a point **r** at time t derived from the **advanced potentials**, i.e., generated by charges and currents that will be at **r** − **R** at time $t + \mathbf{R}/c$ (all **R**).

ADVANCED POTENTIALS. The electromagnetic potentials at a point **r** at time t due to sources at the points **r** − **R** at times $t + |\mathbf{R}|/c$, i.e., on the future **light cone** through the **event** **r**, t.

ADVECTION. The transfer of air and air characteristics by horizontal motion. **Fog** drifts from one place to another by advection. Cold air moves from polar regions southward. Large-scale north-south advection is more prominent in the northern hemisphere than the southern, but west-to-east advection is prominent on both sides of the equator.

ADVECTION FOG. Advection fog is formed when warm moist air comes in contact with a colder surface; this contact with the cold surface cools the air to its dew point, thereby causing condensation and fog. It is a common phenomenon throughout the year over cold ocean currents (for example the Labrador Current) when the air comes from warmer regions.

AEOLIAN TONES. The tones produced by a gas stream striking a stretched wire in a direction normal to the length of the wire. (See also **Strouhal formula**.)

AEOLIGHT. A **glow discharge lamp** employing a cold cathode, and a mixture of permanent gases in which the intensity of illumination varies with the applied **signal voltage.** The aeolight lamp is widely used to produce a modulated light for motion-picture sound recording.

AEOLOTROPIC. Not **isotropic**; having different properties in different directions as in certain crystals; anisotropic.

AERIAL. See **antenna.**

AERODYNAMICS. A phase of the mechanics of fluids, its study being limited to the reactions caused by relative motion between the fluid and solid, with the fluid being air. Sometimes this strict definition is broadened so that *aerodynamics* may also include the reactions of gases other than air. The scope of the subject of aerodynamics is, nevertheless, broad. It encompasses the flow of gases in conduits, the effects of winds on static structures such as building, chimneys, and bridges, and the effect on moving bodies of the atmosphere through which they move.

AEROGEL. A colloidal solution of a gaseous phase in a solid phase, obtained usually by replacement of the liquid in the dispersed phase by air or gas.

AEROLOGY. That branch of **meteorology** which treats of the free atmosphere, i.e., unaffected by surface effects, usually on the basis of direct observations. (2) Aerology is sometimes used as a synonym for meteorology.

AEROMETEOROGRAPH. An instrument made for carrying in an aircraft for the purpose of making an "air sounding," i.e., an investigation of the atmospheric conditions at various levels. The instrument makes a running record of atmospheric pressure, temperature and relative humidity at the various altitudes reached by the aircraft in flight.

AEROMETER. An instrument used to measure the density of gases.

AEROPHARE. An air-navigation **radio beacon.**

AEROSOL. A colloidal system in which a gas, usually air, is the continuous medium, and particles of solid or liquid are dispersed in it.

AEROSTATICS. The science of gases at rest (mechanical equilibrium). (Cf. **aerodynamics,** the science of gases in motion.)

AETHER HYPOTHESIS. See **ether hypothesis.**

AF. Abbreviation for **audio frequency.**

AFFINE. See **coordinate system** and **transformation, affine.**

AFFINELY CONNECTED SPACE. A space with a law of parallel displacement of a vector:

$$\delta a^{\mu} = -\Gamma^{\mu}_{\tau\sigma} a^{\nu} \delta x^{\sigma}$$

$$\delta a_{\mu} = \Gamma'^{\sigma}_{\mu\nu} a_{\sigma} \delta x^{\nu}$$

where the left-hand sides denote changes in the contravariant and covariant components of a vector under the infinitesimal coordinate displacement δx^{μ}.

AFTER-FLOW. Persistence of flow after removal of the external stresses, due to relaxation of visco-elastic stresses.

AFTERGLOW. (1) The persistence of radiation from a **gas-discharge tube** or luminescent screen after the source of excitation has been removed. (2) **Phosphorescence.**

AFTER-IMAGE. The image "seen" after a portion of the retina has been fatigued by continued fixed stimulus. The after-image is frequently of the complementary color to the original stimulus.

AGC. Abbreviation for **automatic gain control.**

AGE, τ. In nuclear reactor theory, the value calculated for the slowing-down area used by Fermi age theory. It is defined by

$$\tau(E, E_0) = \int_{E}^{E_0} \frac{D(E')\, dE'}{\xi\sigma_s(E')\, E'}$$

where E' is the neutron energy, D is the diffusion coefficient of neutron flux, ξ is the logarithmic energy decrement, σ_s is the macroscopic neutron scattering cross-section, that is, the scattering cross-section per unit volume. Note that the "age," being an area, has dimensions of length squared

AGE EQUATION WITHOUT CAPTURE. The equation

$$\nabla^2 q = \frac{\partial q}{\partial \tau}.$$

which describes the slowing down of neutrons in a scattering medium (moderator) in which neutrons are not captured by the nuclei of the moderator. In the equation, q is the slowing down density, or the number of neutrons, per cubic centimeter per second, that slow down past a given energy E; and τ is the "age" (having dimensions of length squared), which is related to the time required by the neutron to slow down, on the average, from its original fission energy to the energy E. (See **Fermi-age model.**)

AGE HARDENING (PRECIPITATION HARDENING). A process of hardening an alloy by aging at room temperature or elevated temperatures, which occurs only in alloys which are supersaturated solid solutions. The aging process, which increases hardness and strength while usually decreasing ductility, is associated with the precipitation of one or more phases which may or may not produce recognizable particles.

AGE OF THE UNIVERSE. A time 5×10^9 years derived from astronomical observations. Whether this is really the age of the universe is a matter of opinion. (See **Hubble constant.**)

AGE THEORY. See **age**; also **Fermi-age model.**

AGENT. A force or substance that acts to produce a change

AGGLOMERATION. The gathering together of particles, for example, the coalescence of smoke particles in air produced by ultrasonic radiation.

AGGREGATE RECOIL. The ejection, from the surface of a sample, of a cluster of atoms attached to one that is recoiling as the result of α-particle emission. Although the phenomenon may be quite common, the amount of matter thus carried away is so small as to be undetectable unless it is strongly radioactive It is observed with strong preparations of α-active materials of high specific activity, such as nearly pure polonium compounds, as a migration of a small fraction of the radioactivity onto clean surfaces in the vicinity.

AGGREGATION. The gathering of particles, especially in the sense of their formation into larger entities or aggregates. An aggregate is a group or collection of particles whose behavior is of special interest. Thus a rigid body is an aggregate of particles in

which the separation distance of every pair of particles remains constant.

AGGREGATION, STATE OF. Physical condition expressed as solid, liquid or gaseous.

AI. Abbreviation for aircraft interception. Refers to airborne **radar** sets used for purposes of interception.

AIEE. Abbreviation for American Institute of Electrical Engineers.

AIR CONDUCTION (SOUND). The process by which sound is conducted to the inner ear through the outer ear canal as part of the pathway.

AIR FOIL. Any body whose shape causes it to receive a useful reaction from an air stream moving relative to it.

AIR GAP. (1) This term is commonly used in connection with various **magnetic circuits,** and denotes a gap left in the magnetic material. In the construction of various **chokes** and **transformers** used in communications circuits, a short gap is usually left in the core material to prevent the material being saturated by the d-c which often flows in such circuits. (See **amplifiers** and **power supplies.**) In rotating electrical machinery the rotating part of the magnetic circuit must of course, be separated by a gap. In these machines this gap is kept as small as consistent with adequate mechanical clearance. In most instances the gap introduces no desirable electrical or magnetic characteristics, and necessitates the application of additional electrical **magnetomotive force** to overcome its **reluctance.** (2) A spark gap, comprising two conducting electrodes, separated by air.

AIR LINES. Spectral lines caused by excitation of molecules in the air by **spark discharges** and which do not ordinarily occur in **arc discharges.** Air lines are mostly undesired in analysis of materials by spectral methods.

AIR MASSES. Very large parcels of air ranging from about 500–5000 miles in lateral dimensions and from several thousand feet to several miles deep, which have properties (temperature, humidity, thermal structure) that vary only slightly, or vary linearly, from point to point within the parcel. Air masses develop over large relatively-homogeneous geographical areas where air is stagnant for a sufficient period to acquire the characteristics of that region. These regions are either continental or maritime and are known as air-mass source regions. After an air mass begins to move from its source region it acquires modifying features characteristic of the surface over which it travels. Modification continues until the air mass loses its identity in the general atmospheric circulation.

Classification of air masses begins from latitudinal consideration. There are four major zones which contribute primary classifications: (1) Arctic, (2) Polar, (3) Tropical, (4) Equatorial.

These are subdivided into Maritime (m) and Continental (c), depending upon the exact source region. Finally each air mass must be classified as either cold (k) or warm (w). A cold air mass is one which is colder than the surface over which it is traveling and is therefore being heated from below. A warm air mass is one which is warmer than the surface over which it is traveling and is therefore being cooled from below.

AIR MONITOR. Any device for detecting and measuring airborne radioactivity for warning and control purposes.

AIR PARCELS, TRAJECTORY OF. See **trajectory of air parcels.**

AIRSPEED METER. See **anemometer.**

AIRY DISK. The central bright part of the **diffraction pattern** of a circular pinhole.

AIRY EXPERIMENT. Demonstration that the angle of aberration (see **aberration of light, Bradley**) of a star does not depend on the nature of the transparent medium filling the telescope.

ALBEDO. (1) The ratio of the light falling on a planet or satellite to that reflected. (2) In nuclear physics, the ratio of the neutron current density out of a (nonsource) medium to the neutron current density into it.

ALBERT EFFECT. A reaction of light-sensitive photographic materials discovered by E. Albert in 1899. Albert found that if a wet collodion plate is considerably overexposed and the latent image destroyed with nitric acid, a positive image is produced upon exposure to white light and subsequent development. Albert's observations with wet collodion have been shown to hold also for ge[illegible]

emulsions by Luppo-Cramer, J. Precht and others. The effect is produced by chromic acid, ammonium persulfate and other substances which destroy the latent image as well as by nitric acid.

ALEXANDERSON ALTERNATOR. A rotating machine used as a source of very low frequency power for purposes of transmission and induction heating.

ALGEBRA. The set of relations between numbers represented by symbols and obtained by the operations of addition, subtraction, multiplication, division, raising to a power, and extracting a root. A common problem is that of finding the value of an unknown quantity satisfying an equation written in terms of the operations just stated.

Functions which involve the variables in algebraic operations are classified into **rational, irrational,** and **power functions.** Algebraic equations containing such functions are called **polynomial, fractional,** or **radical equations.**

ALIGNMENT CHART. See **nomograph.**

ALISONITE ($3Cu_2S \cdot PbS$). A mineral used for early **crystal detectors.**

ALKALI METAL. An element of the first group of the **periodic table,** characterized by the one electron outside the **atomic core** which it readily loses to form a stable **cation.**

ALL-PASS NETWORK. See **network, all-pass.**

ALLEGHENY 4750. Trade name for a nominal 50% nickel-iron, isotropic magnetic alloy.

ALLELOMORPH. (1) One of two or more **isomorphic** substances which consist of the same atoms having the same valences, but differing in their linkages. (2) The first of two or more **isomers** to be recovered or separated from a system.

ALLOBAR. A form of an **element** differing in atomic weight from the naturally-occurring form, hence a form of element differing in isotopic composition from the naturally-occurring form.

ALLOCHROMATIC. Pertaining to a substance, e.g., a crystal, having **photoelectric** properties due to inclusions of microscopic impurities, or as a result of exposure to certain forms of radiation.

ALLOCHROMY. Any fluorescence, or re-radiation of light, in which the wave length (and hence color) of the emitted light differs from that of the absorbed light.

ALLOGYRIC BIREFRINGENCE. A beam of plane-**polarized light** may be regarded as the resultant of two equal beams of circularly polarized light, one right-handed and the other left-handed. The phenomenon of optical rotation may be represented by assuming that in optically-active media, circularly-polarized light is transmitted unchanged, but the velocity of left-handed circularly-polarized light is not the same as that of right-handed circularly-polarized light. Fresnel demonstrated this difference directly, and the phenomenon is called allogyric birefringence (See Ditchburn, *Light,* Chapter 12.)

ALLOMORPHISM. A property of substances that differ in crystalline form but have the same chemical composition.

ALLOTRIOMORPHIC. Characterized by absence of typical crystal faces.

ALLOTROPE. One of the isomeric forms of an element. See **allotropy.**

ALLOTROPY. (Allotropism.) The isomerism of the elements (Richter). A property of certain substances existing in two or more modifications distinct in physical, and some chemical, properties. A good example of allotropy is furnished by sulfur, which exists in a number of forms, two of which are crystalline. These are rhombic sulfur, stable at ordinary temperatures, and monoclinic sulfur, stable above 96°C. However, some substances have more than one form stable in the same range.

ALLOTROPY, DYNAMIC. A class of allotropic phenomena in which the transition from one form to another is reversible but with no definite transition temperature. The proportions of the allotropes depend upon the temperature.

ALLOTROPY, ENANTIOMORPHIC. A class of allotopic phenomena in which the transition from one form to another is reversible and takes place at a definite temperature, above or below which only one form is stable, e.g., the α and β forms of sulfur.

ALLOTROPY, MONOTROPIC. A class of allotropic phenomena in which the transition

is irreversible. One allotrope is **metastable** at all temperatures, e.g., explosive antimony.

ALLOWED BAND. In the **band theory of solids,** a range of energies in which there exist electronic **energy levels.**

ALLOWED TRANSITION. See **transition, allowed.**

ALLOY. Generally speaking, a macroscopically homogeneous mixture of metals. This definition covers an immense class of materials of great technological importance. There are various types of alloys. Thus, the atoms of one metal may be able to replace the atoms of the other on its lattice sites, forming a **substitutional alloy,** or **solid solution.** If the sizes of the atoms, and their preferred structures, are similar, such a **system** may form a continuous series of solutions—otherwise the miscibility may be limited. Solid solutions, at certain definite atomic proportions, are capable of undergoing an **order-disorder transition** into a state where the atoms of one metal are not distributed at random through the lattice sites of the other, but form a **superlattice.** Again, in certain alloy systems, **intermetallic compounds** may occur, with certain highly complicated lattice structures, forming distinct **crystal phases.** It is also possible for light, small atoms to fit into the **interstitial positions** in a lattice of a heavy metal, forming an **interstitial compound.**

ALLOY JUNCTION. See **junction, alloy.**

ALLOY SYSTEM. The whole range of substances obtained by mixing two or more metals in varying proportions, at varying temperatures.

ALLSTRÖM RELAY. A highly sensitive **relay** incorporating a light beam and photocell.

ALL-WAVE ANTENNA. An antenna designed, usually, for reception of the standard broadcast and short-wave bands. This term is ambiguous, and should be avoided in writing.

ALPHA (α). (1) Angular acceleration (α). (2) Plane angle (α). (3) Linear expansion, or coefficient of linear expansion (α). (4) Current amplification in transistors (α). (5) In nuclear reactor theory, (a) the reciprocal asymptotic period, or (b) the ratio, in a fissionable element, of neutron radiative capture (see **capture radiative (2)**) to fission cross-section (α). (6) Thermal diffusibility (α). (7) Optical aperture (α). (8) Attenuation constant (α). (9) Fine structure or Sommerfeld constant (α). (10) Thermal coefficient of resistance (α). (11) Most probable speed (α). (12) Degree of electrolytic dissociation (α). (13) Coefficient of recombination (α). (14) See **alpha-particle** and **alpha-ray.** (15) Plane angle (α). (16) Angular resolving power of telescope (α). (17) Half-angle subtended at point object by objective of microscope (α). (18) Coefficient of recombination (α). (19) Specific rotation (α). (20) Current amplification (α).

ALPHA CHAMBER. A **counter tube** or counting chamber for the detection of **α-particles;** often operated in the non-multiplying **(ionization chamber)** or **proportional region** with pulse height selection to discriminate against pulses due to β- or γ-rays and to pass only those due to α-particles.

ALPHA CHANGE. A nuclear change consisting of the emission of an α-particle.

ALPHA COUNTER. A system for counting **α-particles** including an **α-counter tube,** amplifier, pulse height discriminator, scaler and recorder, or the α-counter tube plus the necessary auxiliary circuits for counting α-particles. Often loosely applied to the α-counter tube or chamber alone.

ALPHA COUNTER TUBE. A counter tube or counting chamber for the detection of **α-particles.** (See **alpha counter.**)

ALPHA CUT-OFF. The frequency at which the alpha **(current amplification)** of a transistor has fallen to 0.7 (3 decibels) of its low-frequency value.

ALPHA DECAY. See **alpha disintegration.**

ALPHA DISINTEGRATION. A nuclear process, consisting of the emission of an **α-particle** from a nucleus, producing a decay product consisting of a nuclide with an **atomic number** two units smaller, and a **mass number** four units smaller than the original nuclide.

ALPHA DISINTEGRATION ENERGY. (1) The energy of disintegration of an α-disintegration process, equal to the value $Q_\alpha = E_\alpha + E_R$ where Q_α is the α-disintegration energy, E_α is the kinetic energy of the α-particle, and E_R is the recoil kinetic energy of the

product atom. If M_α and M_R are the masses of the α-particle and the recoil atom, respectively, then

$$E_\alpha = \frac{M_R}{M_R + M_\alpha} Q_\alpha.$$

and

$$E_R = \frac{M_\alpha}{M_R + M_\alpha} Q_\alpha.$$

(2) Often, the ground state α-disintegration energy, which is the total energy evolved, including the energy of gamma and associated radiations, when the disintegrating and product nuclei are in their ground states: Q_{α_0}.

ALPHA EMITTER. A radionuclide that undergoes a transformation by α-particle emission.

ALPHA PARTICLE. (1) A positively-charged particle emitted from a nucleus and composed of two protons and two neutrons. It is identical in all measured properties with the nucleus of a helium atom. (2) By extension, the nucleus of a helium atom ($Z = 2$, $A = 4$), especially when it is in rapid motion, as when artificially accelerated.

ALPHA PARTICLE(S), DELAYED. α-particles emitted promptly by excited nuclei (see **nucleus, excited**) formed in a **β-disintegration process.** The α-particle emission must occur rapidly enough to compete with de-excitation by γ-ray emission. In this case the α-particles will have an apparent **half-life** equal to that of the β-decay, hence the term "delayed." (See **neutrons, delayed.**)

ALPHA PARTICLE(S), LONG RANGE. See **alpha-particle spectrum.**

ALPHA-PARTICLE MODEL OF NUCLEUS. A nuclear model for which the basic structural unit is the **α-particle.** It is assumed that as many of the nucleons as possible are grouped together to form α-particles and that the remaining nucleons move about somewhat freely. The model is most successful for light nuclei consisting of the same even number of neutrons and protons. Such a nucleus is referred to as an α-particle nucleus.

ALPHA-PARTICLE SPECTRUM. The distribution in energy or momentum of the **α-particles** emitted by a pure radionuclide, or, less commonly, by a mixture of radionuclides. Each α-emitting nuclide yields a characteristic spectrum consisting of one or more sharp lines, each line being due to a particular group of monoenergetic particles. When more than one group is present, the distribution is said to have **fine structure;** this results from transitions to more than one nuclear energy state of the product nuclide, the group of highest energy coming from the ground-state transition. In exceptional cases (RaC′ and ThC′), lines are observed due to groups that have very low intensities (10^{-6} to 10^{-4}) relative to those for the main groups. The particles producing such lines are called long-range α-particles. They result when the emitting nuclei are formed in excited states in the preceding β-disintegration (of RaC or ThC) and emit α-particles directly from the excited states, instead of becoming de-excited by the more usual γ-emission. The normal α-disintegration energy is then augmented by the **excitation energy.**

ALPHA RAY. See **alpha particle.**

ALPHA-RAY SPECTROMETER. An instrument used to determine the energy distribution of **α-particles.**

ALPHATOPIC. Pertaining to a relationship wherein the masses or composition of two nuclei differ by an α-particle.

ALTAITE. A lead telluride mineral, used in early **crystal detectors.**

ALTERNATING CURRENT (A-C). Current in which the charge-flow periodically reverses, as opposed to direct current, and whose average value is zero. Alternating current usually implies a sinusoidal variation of current and voltage This behavior is represented mathematically in various ways:

$$I = I_0 \cos (2\pi ft + \phi)$$

$$I = I_0 \angle \phi$$

$$I = I_1 e^{j\omega t}$$

where f is the frequency; $\omega \equiv 2\pi f$, the pulsatance, or radian frequency; ϕ the phase angle; I_0 the amplitude, and I_1 the complex amplitude. In the complex rotation, it is understood that the actual current is the real part of I.

ALTERNATING CURRENT CIRCUIT. An electrical circuit excited by a-c, rather than by d-c. **Reactance** (see **inductance** and **ca-**

pacitance) must be considered as well as **resistance.** By using complex-number algebra and the concept of impedance, a-c circuits can be solved like d-c circuits with a generalization of the **Ohm law** to

$$E = ZI$$

The *actual* instantaneous voltage and current are:

$$e(t) = \text{Re}\, E = \tfrac{1}{2}\{E_0 e^{j\omega t} + \tilde{E}_0 e^{-j\omega t}\}$$

$$i(t) = \text{Re}\, I = \tfrac{1}{2}\{I_0 e^{j\omega t} + \tilde{I}_0 e^{-j\omega t}\}$$

where the symbol $\sim$ indicates the **complex conjugate.**

The instantaneous power delivered is

$$\begin{aligned} P(t) = ei &= \tfrac{1}{4}(E_0\tilde{I}_0 + \tilde{E}_0 I_0) \\ &\quad + \tfrac{1}{4}(E_0 I_0 e^{2j\omega t} + \tilde{E}_0\tilde{I}_0 e^{-2j\omega t}) \\ &= \tfrac{1}{2}\,\text{Re}\,(E_0\tilde{I}_0) + \tfrac{1}{2}\,\text{Re}\,(E_0 I_0 e^{2j\omega t}) \\ &= \tfrac{1}{2}R|I_0|^2 + \tfrac{1}{2}\,\text{Re}\,(E_0 I_0 e^{2j\omega t}) \end{aligned}$$

since $I_0\tilde{I}_0 = |I_0|^2$, and $\text{Re}\, Z = R$. Thus the power has a constant component $\tfrac{1}{2}R|I_0|^2$ and a double-frequency, alternating component whose average value is zero. The average power may be written

$$P_{av} = \tfrac{1}{2}R|I_0|^2 = \tfrac{1}{2}|E_0| \cdot |I_0| \cos\theta$$

where θ is the phase angle between the voltage and current, and is given by

$$\cos\theta = R/|Z|$$

The phase angle correction factor, $\cos\theta$, is known as the power factor.

ALTERNATING-CURRENT CIRCUIT(S), APPLICATION OF COMPLEX QUANTITIES TO. In **alternating-current circuits,** the voltage, current, and impedance have both magnitude and phase. It is convenient to represent such quantities by "phasors":

$$Ae^{j(\omega t+\phi)}, \quad |Z|e^{j\theta}$$

This device permits the generalization of the **Ohm law** to the a-c case: $V = ZI$, with all quantities being represented by complex numbers. In this way, both **amplitude** and **phase** are carried along in a simple manner.

ALTERNATION, LAW OF. The **spectra** of the elements in successive groups of the **periodic table** of elements are characterized by alternations of odd and even term **multiplicities.** Thus the arc spectrum of potassium has a multiplicity of 2, calcium has values of 1 and 3, scandium, 2 and 4, titanium, 1, 3, and 5, etc. In general, the elements of even valence have odd multiplets, whereas those of odd valence have even multiplets. A spectral multiplicity or multiplet is the number of spectral lines in an associated group of fine lines relatively close together.

ALTERNATOR. A device for converting mechanical energy into electrical energy, the latter appearing as an **alternating current.** The simplest alternating current generator

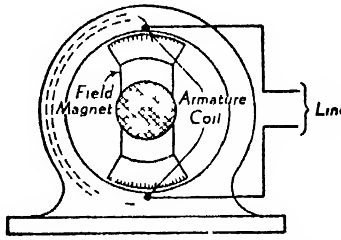


Fig. 1. Elementary alternator.

consists of a coil of wire rotating in a constant magnetic field. The elementary principle of a simple two-pole, single-phase alternator is shown in Fig. 1. When the magnet revolves it will carry with it lines of force which will cut the conductor, which is a wire loop embedded in the stationary portion called the armature, and will generate a-c.

This elementary principle must be expanded in several directions if a practical generator of a-c is to be had. First, the rotating part, or rotor, must have magnetic strength in excess of that which could be obtained from a simple permanent magnet. In other words, the poles must be formed by electromagnets whose excitation, in the form of d-c, must be carried to the rotor through slip-ring connections. The rotor is called the field, and the current it uses is called the field current. In high-speed steam-turbine driven **alternators** as few as two poles are often used, while in slow-speed water-turbine units the number is frequently nearly 100. The stationary part, called the stator, or armature, usually has three sets of overlapping coils, connected in three separate circuits. These three circuits, or phases, are usually connected in one or the

other ways shown in Fig. 2. The Y connection is preferred because of the usefulness of the neutral point, and the fact that the line voltage is $\sqrt{3}$ times the phase voltage, whereas it is only equal to the phase voltage in Δ connection. The neutral point is connected to the fourth wire of a four-wire, three-phase system, and left unconnected, or grounded, in the three-wire system. Several advantages are realized by making the rotating part the **field,** and the stationary part the **armature.** The a-c may be generated at very high voltages because it is not necessary to connect it

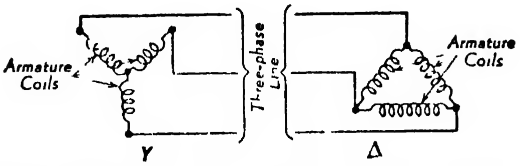


Fig 2 Comparison of y and Δ connections of three-phase alternator windings

through movable contacts as would be the case if the armature revolved. It is not necessary to conduct high-load currents through slip rings and **brushes** if the armature is fixed. The armature conductors can be very rigidly braced in position, and may be much better disposed than if they were required to be in the rotor.

ALTERNATOR, ALEXANDERSON. See **Alexanderson alternator.**

ALTERNATOR TRANSMITTER. See **transmitter, alternator.**

ALTIMETER. An instrument for indicating altitude above or below a given datum point, usually the ground or sea level. The most common form is based on the variation of atmospheric pressure with altitude.

ALTIMETER, CAPACITANCE. An **altimeter** which determines the height of an aircraft in terms of its **capacitance** to earth.

ALTOCUMULUS. Billowed **cloud** of small cumuli (see **cumulus**) that generally form in layers. It is composed of water droplets, although it may lie either above or below the freezing level. It is a middle-level cloud. Altocumulus casts shadows and varies in color from pure white to nearly black. In general they are whitish with darker shadows. "Mackerel sky" is an appropriate description for many altocumulus bands. The cloud may or may not be associated with cyclonic storms.

ALTOSTRATUS. Translucent to opaque **cloud** composed of water droplets through thin layers of which the sun or moon might appear as seen on a ground-glass screen. It is a middle-level cloud in contrast to the high **cirrus** forms but may lie either above or below the freezing level. Very frequently, the top part of a layer of altostratus is a cirrus-type cloud, although this is not observable from below. Altostratus cast very little if any shadow but usually appear as a dull, drab, grayish sheet. Altostratus following cirrus and **cirrostratus** is an almost certain indication that a cyclonic disturbance is approaching.

ALUMINUM. Metallic element. Symbol Al. Atomic number 13.

A M. Abbreviation for **amplitude-modulation.**

AMAGAT-LEDUC RULES. Volume occupied by a mixture of gases is equal to the sum of the volumes they would occupy individually at the temperature and pressure of the mixture.

AMAGAT UNITS. A system of units in which the unit of pressure is the atmosphere, and the unit of volume is the gram-molecular volume (22.4 liters at standard conditions).

AMBIENT TEMPERATURE. The temperature of the surrounding medium, such as gas or liquid.

AMERICIUM. Transuranic radioactive element. Symbol Am. Atomic number 95.

AMETROPIC. Eyes which are myopic or hyperopic are said to be ametropic.

AMICI PRISM. See **prism, Amici.**

AMICRON. A name applied by Zsigmondy to individual disperse particles invisible under the ultramicroscope whose size is about 10^{-7} cm. They act as nuclei for the formation of submicrons which are about five times as large.

AMMETER. An instrument for measuring electric currents in amperes. D-c ammeters are usually of the moving-coil type, being similar in principle to the d'Arsonval **galvanometer.** A coil carrying the current to be

measured turns between the poles of a permanent magnet against the torque of a hairspring and causes a pointer to move over its dial. A-c ammeters sometimes have two coreless coils in series, one turning in the field set up by the other which is fixed (electrodynamometer type). The reversal of current thus has no effect upon the direction of the torque. The most commonly-used a-c ammeters employ a vane of iron which may move in the magnetic field of a coil, thus changing the inductance of the coil (moving-vane type). Some simple ammeters are of the hot-wire type, in which the longitudinal expansion of the wire carrying the current controls the movement of the pointer For currents heavier than the coil or the hot wire can safely stand, a shunt may be provided in d-c ammeters, which allows only a predetermined fraction of the current to pass through the instrument; while a transformer serves a similar purpose with a-c ammeters. Sensitive ammeters, graduated in milliamperes, are called milliammeters.

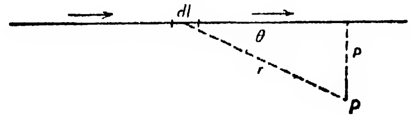
AMORPHOUS. Devoid of regular structure, like glass as distinguished from a crystal.

AMPERE. A unit of electrical current, abbrev. as A or amp. (1) The absolute ampere is exactly one-tenth of an abampere, the electromagnetic unit (emu) of current The absolute ampere has been the legal standard of current since 1950. (2) The International ampere, the legal standard prior to 1950, is the steady current which must flow across a surface in order that one International coulomb of electricity shall pass the surface during each second. 1 Int. amp = 0.999835 Abs. amp.

AMPERE-HOUR. A unit of electrical charge, being the amount of electricity represented by a current of one **ampere** flowing for one hour.

AMPERE LAW. This is a classic law of electromagnetism, useful in discussions of electrodynamics. It has been stated in two apparently distinct forms, which are, however, interconvertible.

One form, sometimes known as the **Laplace law**, states that the electric current i **(abamperes)**, flowing along any line through an element of length dl, gives rise, at a point P distant r (cm) from the element, to a magnetic field of intensity $dH = ipdl/r^3$ **(oersteds)**, in which p is the perpendicular distance from P to the line of the element dl; or $dH = i \sin \theta dl/r^2$, in which θ is the angle between the line of the element and the line joining dl to P. (See **vector potential.**) The ultimate basis of the law is, of course, experi-



mental. It may, for example, be deduced indirectly from the **Biot-Savart** law for the field about an infinitely long, straight wire. Ampere's law furnishes a basis for the solution of all problems relating to the magnetic fields produced by electric currents.

What is sometimes called the circuital form of Ampere's law may be tangibly expressed by saying that if a unit magnetic pole is carried completely around a conductor or system of conductors in which electricity is flowing, in such a way as to oppose the field set up by the currents, the work done, in **ergs**, is 4π times the algebraic sum of the currents, in abamperes. This is easily illustrated by a special case The Biot-Savart law above referred to gives, as the magnetic field at a point distant r (cm) from an infinitely long, straight wire carrying a current i (abamperes), the value $H = 2i/r$ (oersteds), directed, of course, along the circumference of the circle having r as its radius. The force acting upon a unit pole placed at this point is therefore $2i/r$ **(dynes).** If now the pole is moved around the circle, against the field, the work done is

$$\frac{2i}{r} \times 2\pi r = 4\pi i \text{ (ergs).}$$

Maxwell pointed out that Ampere's law holds only for constant currents, and that when currents vary, the resulting changes of electric displacement in the surrounding space, giving rise to the radiation of energy in the form of electromagnetic waves, involves modifications embodied in the so-called Maxwell-Ampere law as expressed by the first of **Maxwell's equations.** The differential form of Ampere's law cannot be experimentally verified; we can observe only the field due to a closed current loop, not from isolated elements. Experimentally, we can verify that the result of integrating the Ampere law over any closed circuit gives the correct result.

AMPERE RULE. The **magnetic flux** generated by a current in a wire encircles the current in the counter-clockwise direction, if the current is approaching the observer.

AMPERE THEOREM. The **magnetic field** due to an electric **current** flowing in any circuit is equivalent at external points to that due to a simple magnetic shell, the bounding edge of which coincides with the conductor, and the strength of which is equal to the strength of the current. (See **magnetic shell, equivalent.**)

AMPERE THEORY OF MAGNETISM. The hypothesis that permanent **magnetic moment** is due to permanent, internal, current loops in a material.

AMPERE TURN. A measure of **magnetomotive force.** (See also **ampere-turn per meter.**)

AMPERE-TURN AMPLIFICATION. See **amplification, ampere-turn.**

AMPERE-TURN GAIN. In magnetic amplifiers, the ratio of the product of **load current** and **gate turns** to the product of **control current** and **control turns.**

AMPERE-TURN PER METER. A measure of magnetizing force H. (The magnitude of H at any point in a magnetic circuit depends on the current, the number of turns, and the **geometry** of the circuit.)

AMPERE-TURN RATIO. See **ampere-turn gain.**

AMPERE-TURNS, CONTROL. The term control ampere-turns expresses the magnitude and polarity of the control **magnetomotive force** required for operation of a **magnetic amplifier** at a specified output.

AMPERE-TURNS, CONTROL, NOMINAL. The difference between the control ampere-turns for minimum output and for rated output is the nominal control ampere-turns difference, or briefly, control ampere-turns.

AMPERITE. Trade name for a **ballast tube.**

AMPLIDYNE. A rotary **magnetic** or dynamo-electric **amplifier** frequently used in **servomechanism** and control applications because of its high power gain. It is a single-stage device with a high degree of positive **feedback.**

AMPLIFICATION. A general transmission term used to denote an increase of signal magnitude.

AMPLIFICATION, AMPERE-TURN. Of a **magnetic amplifier,** the ratio of the change in output ampere-turns to the change in control ampere-turns required to produce the output current change. Assuming the change from minimum to maximum output ampere-turns to be 100%, the nominal ampere-turn amplification will be measured over the following range: An output current 20% greater than the minimum to an output current 20% less than the maximum. Ampere-turn amplification should be specified for operations of the magnetic amplifier at its rating except for control currents and output currents. The ampere-turn amplification shall be the minimum that exists for any conditions within the rating.

AMPLIFICATION CONSTANT OF RESONATOR. The ratio of the square of the maximum excess pressure in a **resonator** to the square of the maximum external operating pressure. (See also **sound pressure, maximum.**)

AMPLIFICATION, CURRENT. See **current amplification.**

AMPLIFICATION FACTOR. This is a commonly used parameter in vacuum-tube work and is usually denoted by μ. In the conventional **tube** the current is controlled both by the voltage applied to the **grid** and that applied to the **plate.** Because the grid is closer to the **cathode** from which the **electrons** are drawn, a voltage applied to it is more effective in drawing the electrons across the tube than would be the same voltage applied to the plate (it is the passage of these electrons across the cathode-anode space which constitutes the tube current). Amplification factor is a measure of the relative effectiveness of voltages on the two electrodes and is defined as the negative of the ratio of the infinitesimal plate voltage change necessary to counteract a given infinitesimal change in grid voltage in order to keep the plate current constant.

$$\mu = \left(-\frac{\partial V_p}{\partial V_g}\right)_{i_p \text{ constant}}$$

AMPLIFICATION, MAGNETIC. Amplification achieved by the utilization of the non-

linear properties of saturable magnetic cores. (See **amplifier, magnetic.**)

AMPLIFICATION, POWER. (1) In an amplifier, the ratio of the power level at the output terminals to that at the input terminals.

(2) In a magnetic amplifier, the product of the voltage amplification and the current amplification of that amplifier, using a specified control circuit. (See **amplification, voltage** and **amplification, current.**)

(3) In a transducer the ratio of the power that the transducer delivers to a specified load, under specified operating conditions, to the power absorbed by its input circuit.

If the input and/or output power consist of more than one component, such as multifrequency signal or noise, then the particular components used and their weighting must be specified. This ratio is usually expressed in decibels.

AMPLIFICATION, VOLTAGE. (1) The ratio of the voltage produced at the output terminals of an **amplifier,** as a result of the voltage impressed at the input, to the voltage impressed at the input. (2) The ratio of the magnitude of the voltage across a specified load impedance connected to a **transducer,** to the magnitude of the voltage across the input of the transducer. If the input and/or output voltage consist of more than one component, such as multifrequency signal or noise, then the particular components used and their weighting should be specified. By custom this amplification is often expressed in decibels by multiplying its common logarithm by 20. (3) Of a **magnetic amplifier** control-winding, the ratio of the change in output voltage to the change of voltage across the control winding circuit required to produce the output voltage change. Assuming the change from maximum to minimum output voltage to be 100%, the nominal voltage amplification will be measured over the following range: An output voltage 20% greater than the minimum to an output voltage 20% less than the maximum. Voltage amplification should be specified for operations of the magnetic amplifier at its rating except for control currents and output currents. The voltage amplification shall be the minimum that exists for any conditions within the rating.

AMPLIFIER. A device whose output is a function of its input signal, and which draws power therefor from a source other than the input signal. In addition to definitions of various types of amplifiers, the following articles include two long articles on basic types. (See **amplifier, magnetic** and **amplifier, vacuum-tube.**)

AMPLIFIER, BALANCED (PUSH-PULL). An **amplifier circuit** in which there are two identical signal branches connected so as to operate in **phase opposition** and with input and output connections each balanced to ground.

AMPLIFIER, BOOSTER. An amplifier used in audio consoles between mixer controls and the master volume control to prevent deterioration of **signal-to-noise ratio.** It generally supplies sufficient **gain** to compensate for mixing-circuit losses.

AMPLIFIER, BOOTSTRAP. See **bootstrap circuit.**

AMPLIFIER, BUFFER. An **amplifier** in which the reaction of output-load-impedance variation on the input circuit is reduced to a minimum for isolation purposes.

AMPLIFIER, CASCADE OR MULTISTAGE. A chain of amplifier stages in which the output of the first is used as the input of the second, and so on. A stage of such an amplifier is defined as the section from a point just before the grid of one tube to that just before the grid of the next.

AMPLIFIER, CASCODE. A cascade amplifier consisting of a grounded-cathode input stage driving a grounded-grid output stage. Frequently used in television and other UHF and VHF receiver input-stages because of its low **noise figure.** Sometimes referred to as the "Wallman Amplifier" for its originator.

AMPLIFIER, CATHAMPLIFIER. See **cathamplifier.**

AMPLIFIER, CATHODE-COUPLED. A cascade amplifier (see **amplifier, cascade**) in which the coupling between two stages is obtained by the use of a common cathode resistor.

AMPLIFIER, "CATHODE-FOLLOWER." See **amplifier, grounded-plate.**

AMPLIFIER, CHIRIEX. An infrequently-used, high-efficiency, linear radio-frequency amplifier.

AMPLIFIER, "CHOPPER." A synonym for **amplifier, contact-modulated.**

AMPLIFIER CIRCUIT. See **amplifier.**

AMPLIFIER, CLASS-A. An **amplifier** in which the **grid bias** and alternating grid voltages are such that **plate current** in a specific tube flows at all times. To denote that grid current does not flow during any part of the input cycle, the suffix 1 may be added to the letter or letters of the class identification. The suffix 2 may be used to denote that grid current flows during some part of the cycle. The same notation is used in the Class AB, Class B and Class C amplifiers.

AMPLIFIER, CLASS-AB. An **amplifier** in which the **grid bias** and alternating grid voltages are such that **plate current** in a specific tube flows for appreciably more than half but less than the entire electrical cycle.

AMPLIFIER, CLASS-B. An **amplifier** in which the **grid bias** is approximately equal to the **cutoff value** so that the **plate current** is approximately zero when no exciting grid voltage is applied, and so that plate current in a specific tube flows for approximately one-half of each cycle when an alternating grid voltage is applied.

AMPLIFIER, CLASS-C. An **amplifier** in which the **grid bias** is appreciably beyond the **cutoff** so that the **plate current** in each tube is zero when no alternating grid voltage is applied, and so that plate current flows in a specific tube for appreciably less than one-half of each cycle when an alternating grid voltage is applied.

AMPLIFIER, CONTACT-MODULATED. An **amplifier** for the amplification of d-c and very low frequency signals. The signal source is modulated by a carrier-operated **contact system** (usually 60 or 400 cps), the resulting modulated wave amplified in an a-c amplifier to a suitable level, and subsequently demodulated, sometimes by the same contact system used to accomplish the original modulation

AMPLIFIER, DIELECTRIC. An **amplifier** which utilizes as a controllable impedance a capacitive element whose capacitance is a function of applied voltage.

AMPLIFIER, DIRECT-CURRENT. An **amplifier** capable of amplifying waves of infinitesimal frequency.

AMPLIFIER, DISTRIBUTED. An **amplifier** consisting of vacuum tubes appropriately distributed along **artificial transmission lines.** This amplifier is capable of much greater band-widths than a conventional amplifier, and the ordinary **figure of merit** or **gain-band width** product does not apply.

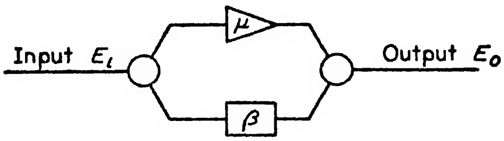
AMPLIFIER, DOHERTY. A particular arrangement of a radio-frequency linear **power amplifier** wherein the **amplifier** is divided into two sections whose inputs and outputs are connected by quarter-wave (90°) networks, and whose operating parameters are so adjusted that, for all values of the input signal voltage up to one-half maximum amplitude, Section No. 2 is inoperative and Section No 1 delivers all the power to the load, which presents an impedance at the output of Section No. 1 that is twice the optimum for maximum output. At one-half maximum input level, Section No. 1 is operating at peak efficiency, but is beginning to saturate. Above this level, Section No. 2 comes into operation, thereby decreasing the impedance presented to Section No. 1, which causes it to deliver additional power into the load until, at maximum signal input, both sections are operating at peak efficiency, and each section is delivering one-half the total output power to the load

AMPLIFIER, DOUBLE-STREAM. A **traveling-wave amplifier** in which the amplification occurs as a result of the interaction of two electron beams having different average velocities. The amplification takes place in the beam itself and is a result of what might be called electromechanical interaction.

AMPLIFIER, DYNAMO-ELECTRIC. A power amplifier for d-c and very low frequencies whose output circuit consists of some form of rotating armature in a controllable magnetic field. It is frequently employed in servomechanisms and other control systems. See **amplidyne, metadyn** and **rototrol.**

AMPLIFIER, FINAL. The last **amplifier** stage in a radio transmitter.

AMPLIFIER, FEEDBACK. In its simplest form, a feedback amplifier can be regarded as a combination of an ordinary **amplifier** or μ circuit, and a **passive network,** or β circuit, by means of which a portion of the μ circuit



can be returned to its input. The resulting relationship between output and input voltage is

$$E_0 = \frac{\mu}{1 - \mu\beta} E_i$$

where $\mu\beta$ is called the feedback factor and can be either plus (positive feedback) or minus (negative feedback), and μ itself is the **amplification factor** of the μ circuit.

AMPLIFIER, GROUNDED-CATHODE. An electron-tube **amplifier** with the cathode at ground potential at the operating frequency, with input applied between the **control grid** and ground, and the output load connected between plate and ground. (This is the conventional amplifier circuit.)

AMPLIFIER, GROUNDED-GRID. An electron-tube **amplifier circuit** in which the **control grid** is at ground potential at the operating frequency, with input applied between cathode and ground, and output load connected between plate and ground. The grid-to-plate impedance of the tube is in parallel with the load instead of acting as a **feedback** path.

AMPLIFIER, GROUNDED-PLATE (CATHODE FOLLOWER). An electron-tube **amplifier circuit** in which the plate is at ground potential at the operating frequency, with input applied between grid and ground, and the output load connected between cathode and ground. A grounded-plate amplifier is characterized by a large negative feedback, and is often used as an impedance-matching device.

AMPLIFIER, HEAD. The **amplifier** used to amplify the audio-frequency output of the sound head of a motion-picture projector.

AMPLIFIER, HYDRAULIC. A power amplifier (see **amplifier, power**) employed in some servomechanisms and control systems in which power amplification is obtained by the control of the flow of a high pressure liquid by a valve mechanism.

AMPLIFIER, INTERMEDIATE-FREQUENCY. The **amplifier** used in **superheterodyne** receivers which amplifies the sum or difference frequency produced in the **mixer** or first detector by the heterodyning of the signal and oscillator frequencies.

AMPLIFIER, INVERTED. See **amplifier, step-down.**

AMPLIFIER, LINEAR POWER. A power amplifier (see **amplifier, power**) in which the signal output voltage is directly proportional to the signal input voltage.

AMPLIFIER, LOCK-IN. See **detector, synchronous.**

AMPLIFIER, LOGARITHMIC. An **amplifier** whose output signal is a logarithmic function of the input signal.

AMPLIFIER, MAGNETIC. A device using **saturable reactors** either alone or in combination with other circuit elements to secure amplification or control.

AMPLIFIER, MAGNETIC, BALANCED. A device formed by mixing the outputs of two identical single-ended amplifiers so that the output polarity can be reversed.

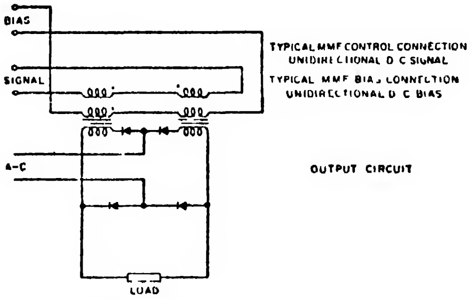
AMPLIFIER, MAGNETIC, BALANCED, CLASS A OPERATION. Class A operation of a balanced amplifier occurs when each single-ended amplifier is biased so that it conducts when the input signal is zero.

AMPLIFIER, MAGNETIC, BALANCED, CLASS B OPERATION. Class B operation of a balanced amplifier occurs when each single-ended amplifier is biased to cut-off so that neither amplifier conducts when the input signal is zero.

AMPLIFIER, MAGNETIC, BALANCED, CLASS C OPERATION. Class C operation of a balanced amplifier occurs when each of

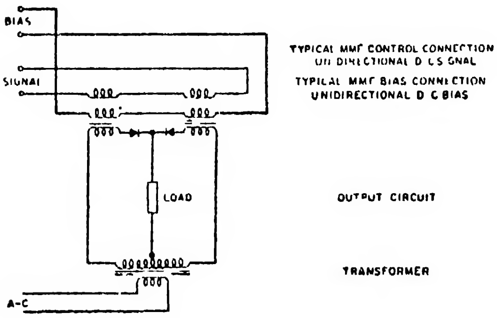
the single-ended amplifiers is biased appreciably beyond the cut-off value so that neither amplifier conducts when the input signal is zero.

AMPLIFIER, MAGNETIC, BRIDGE CIRCUIT. See figure.



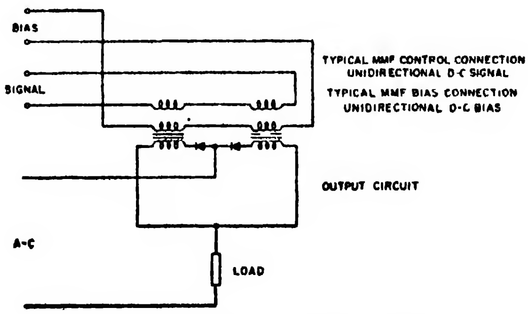
Magnetic amplifier bridge circuit

AMPLIFIER, MAGNETIC, CENTER-TAP CIRCUIT. See figure.



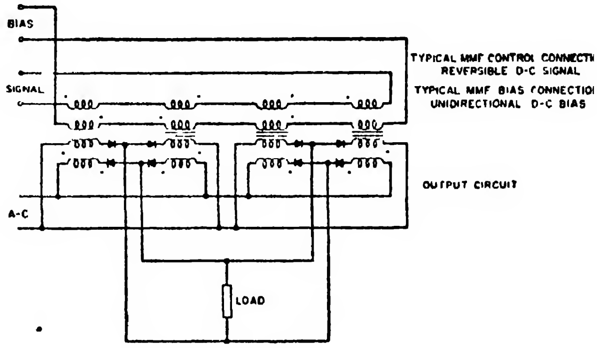
Magnetic amplifier center-tap circuit

AMPLIFIER, MAGNETIC, DOUBLER CIRCUIT. See figure.



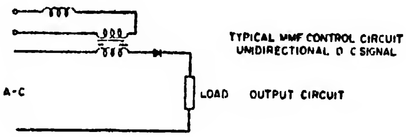
Magnetic amplifier doubler circuit

AMPLIFIER, MAGNETIC, FULL-WAVE BRIDGE CIRCUIT. This circuit is shown in the accompanying figure. It provides a reversible output for a servo-motor.



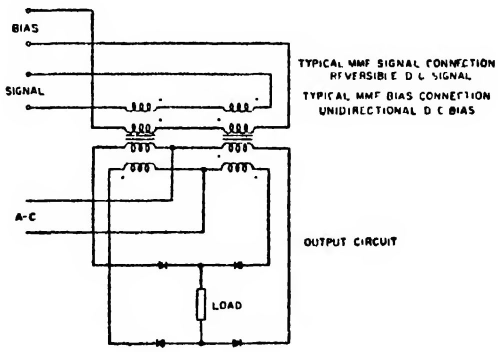
Magnetic amplifier full-wave bridge circuit

AMPLIFIER, MAGNETIC, HALF-WAVE CIRCUIT. See figure.



Magnetic amplifier half-wave circuit

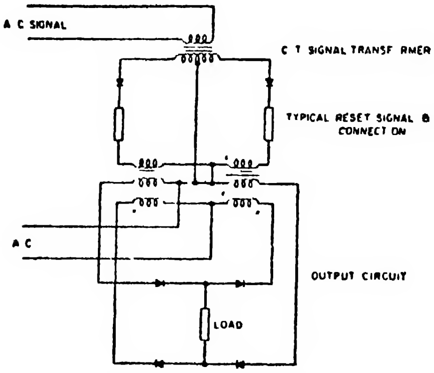
AMPLIFIER, MAGNETIC, HALF-WAVE BRIDGE CIRCUIT. This circuit is shown in the accompanying figure. It provides re-



Magnetic amplifier half-wave bridge circuit

versible output for a servo-motor; and it does not employ cross-conduction.

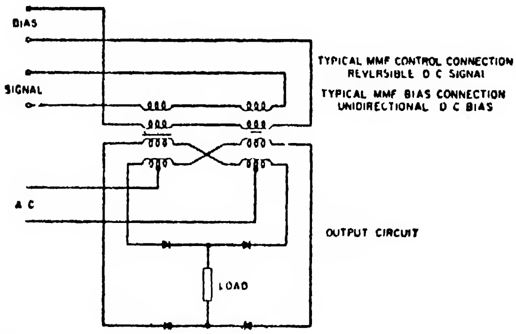
AMPLIFIER, MAGNETIC, HALF-WAVE BRIDGE CIRCUIT (WITH CROSS-CONDUCTION). This circuit is shown in the accompanying figure It provides a reversible



Magnetic amplifier half-wave bridge circuit (with cross-conduction)

output for a servo-motor and it employs cross-conduction.

AMPLIFIER, MAGNETIC, HALF-WAVE BRIDGE CIRCUIT (AUTOTRANSFORMER). This circuit is shown in the accompanying figure It provides a reversible out-



Magnetic amplifier half-wave bridge circuit (with cross-conduction and autotransformer)

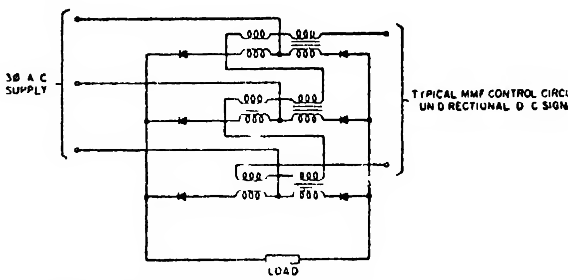
put for a servo-motor; and it employs an autotransformer with cross-conduction

AMPLIFIER, MAGNETIC, SIMPLE. A **magnetic amplifier** consisting only of **saturable reactors.**

AMPLIFIER, MAGNETIC, SIMPLE PARALLEL. A simple magnetic amplifier having two a-c coils which are parallel-connected.

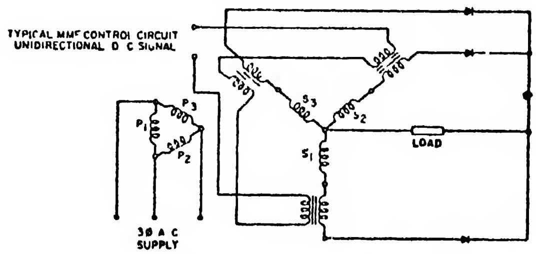
AMPLIFIER, MAGNETIC, SIMPLE SERIES. A simple magnetic amplifier (see **magnetic amplifier, simple**) having two a-c coils which are series-connected. The three-legged type in which the a-c coil is on the center leg may be considered of this type.

AMPLIFIER, MAGNETIC, THREE-PHASE FULL-WAVE BRIDGE CIRCUIT. See figure



Magnetic amplifier three-phase full-wave bridge circuit

AMPLIFIER, MAGNETIC, THREE-PHASE HALF-WAVE CIRCUIT. See figure.



Magnetic amplifier three-phase half wave circuit

AMPLIFIER, MAGNETIC, VOLTAGE-CONTROLLED. A **magnetic amplifier** in which the rate of saturable reactor core flux change during the resetting interval and, consequently the reset flux level are directly related to the signal voltage and are not sensibly affected by such currents as may flow in the control circuit.

AMPLIFIER, MODULATED. An **amplifier** stage in a **transmitter** in which the **modulating** signal is introduced and modulates the carrier.

AMPLIFIER, MONITORING. In broadcasting and recording: an **amplifier** with high input impedance and medium power output which is bridged across the program circuit. The available power output is used to operate a loudspeaker and/or headphones for the benefit of control personnel.

AMPLIFIER, NEHER TETRODE. An integral-cavity, negative-grid tube designed to operate at a frequency of about 3000 **mega-cycles** per second.

AMPLIFIER, NON-LINEAR. An **amplifier** in which the output is not related to the input by a simple constant. One form is the volume-limiting amplifier (see **amplifier, volume limiting**) where the average gain is changed in such a manner that steady-state waveforms are accurately reproduced; another form, frequently called a clipping or over-driven amplifier, has an output which is a greatly distorted version of the input.

AMPLIFIER, PARAPHASE. A **phase-inverter** amplifier used to convert a **single-ended signal** to a **push-pull signal.**

AMPLIFIER, PEAK-LIMITING OR GAIN ADJUSTING. See amplifier, **volume-limiting.**

AMPLIFIER, PENTRIODE. A **video amplifier** containing a **pentode** which, by virtue of suitable bypass and coupling devices, is made to operate as a **triode** (screen effectively connected to the plate) over a portion of the frequency range, and as a pentode (screen-grounded) over another part of the frequency range.

AMPLIFIER, POWER. An **amplifier** designed to produce maximum output power rather than maximum voltage gain for a given percent distortion.

AMPLIFIER POWER AMPLIFICATION. See **amplification, power.**

AMPLIFIER, PROGRAM. The **amplifier** following the **master volume control** in an audio console. Its gain brings the signal to a level suitable for transmission.

AMPLIFIER, PUSH-PULL. See **amplifier, balanced.**

AMPLIFIER, REGENERATIVE. An amplifier with positive feedback. (See **amplifier, feedback.**)

AMPLIFIER, RIPPLED WALL. A type of single-velocity, stream **amplifier** in which the major part of the amplification is obtained in a **drift-tube region,** where either the tube diameter or the stream diameter varies periodically.

AMPLIFIER, SERVO. The name applied to any **amplifier** used as a part of a **servomechanism.**

AMPLIFIER, SINGLE-ENDED. An **amplifier** in which each stage normally employs only one tube, or, if more than one tube is used, in which they are connected in parallel so that operation is asymmetric with respect to ground.

AMPLIFIER, SINGLE-ENDED PUSH-PULL. A form of **amplifier** in which a pair of output terminals may have an instantaneous voltage of either polarity as may be dictated by the phase of the input signal.

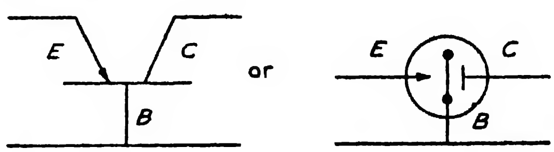
AMPLIFIER, STAGGER-TUNED. An **amplifier** incorporating **stagger-tuning** to provide a desired bandwidth characteristic.

AMPLIFIER, STEP-DOWN. An **amplifier** used to measure very high potentials which are impressed between anode and cathode, the anode being negative. The corresponding grid current is measured with the grid positive. This is sometimes called an "inverted voltmeter."

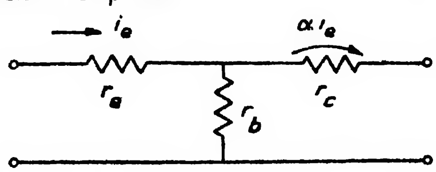
AMPLIFIER, TIME-SHARED. An **amplifier** which may be used for several signals by virtue of a synchronous switching arrangement which connects one signal, and the appropriate source, at a time to the amplifier. This process actually consists of a complete time-division multiplex modulation system. (See **modulation, multiplex, time-division.**)

AMPLIFIER, TRANSISTOR. The **transistor** may be employed as an amplifier in three basic configurations; the grounded-base, the grounded-emitter, and the grounded-collector.

(1) The grounded-base transistor amplifier has less than unity current amplification (for transistors with $\alpha < 1$), no phase reversal; very low input impedance; and high output impedance

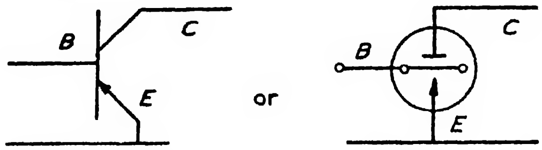


Schematic representation of the grounded-base transistor amplifier

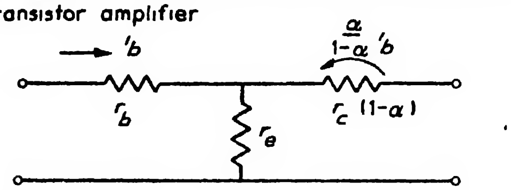


One equivalent circuit of a grounded-base transistor amplifier

(2) The grounded-emitter transistor amplifier has the largest power gain of the three configurations; large current amplification, input impedance relatively low and essentially independent of load; phase reversal.

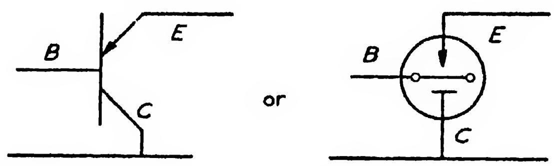


Schematic representation of grounded-emitter transistor amplifier

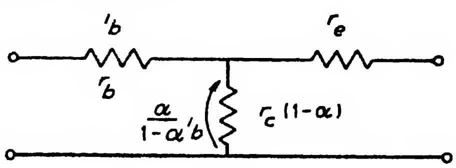


One equivalent circuit of a grounded-emitter transistor amplifier

(3) The grounded-collector transistor amplifier has the lowest power gain of the three configurations, large current amplification; no phase reversal, input impedance quite high but dependent on output impedance; output impedance quite low but dependent on input impedance.



Schematic representation of grounded-collector transistor amplifier



One equivalent circuit of a grounded-collector transistor amplifier

(See also **transistor, parameter** entries.)

AMPLIFIER, TRANSISTOR, COMPLEMENTARY. A transistor amplifier which makes use the complementary symmetry of the characteristics of NPN and PNP transistors. As an example, an NPN transistor and a PNP transistor might be placed in a grounded-emitter, push-pull output circuit with their bases directly in parallel. A positive input signal will cause an increase in collector current in the NPN and decrease in collector current in the PNP transistor. Thus push-pull operation is achieved without a transformer or usual form of **phase-invertor.**

AMPLIFIER, TRIODE. An amplifier employing a **triode electron tube.**

AMPLIFIER, TUNED. An **amplifier** in which the load impedance consists of, generally, a parallel inductance-capacitance network. The fact that the impedance of this network varies with frequency causes the gain of the amplifier to vary as a function of frequency in a somewhat similar manner.

AMPLIFIER, VACUUM TUBE. An amplifier which has a vacuum tube and its associated circuit arranged to reproduce in its plate circuit in greater magnitude a voltage or current which is applied in its grid circuit. The term amplifier is used to denote both a single stage or several stages in cascade. Vacuum-tube amplifiers are classified in various ways according to their use, circuit, etc., but all types depend upon a few basic circuits. Thus they may be termed current amplifiers or voltage amplifiers, power amplifiers, audio-frequency amplifiers, radio-frequency amplifiers and various coupling types.

Current amplifiers are designed to give an amplified current in the plate circuit. However, since the vacuum tube is a voltage-controlled device, the input current is applied to the grid as a voltage drop that is produced in an impedance. This voltage drop controls the current in the plate circuit which is designed to give relatively large currents. Voltage amplifiers on the other hand have their plate circuits designed to produce large voltage drops.

In any vacuum-tube amplifier circuit the fundamental operation is the controlling of the plate current by a voltage applied to the grid. This plate-current change is utilized in various ways, giving rise to several standard classifications of voltage amplifiers. Reference to the figures will aid in understanding the operation. Fig. 1*a* shows a simple resistance-coupled circuit. The a-c voltage to be amplified is applied across the grid resistor r_g. This voltage alters the plate current which varies as the grid voltage varies. For no-signal voltage on the grid, plate current is a constant value of d-c, but the a-c voltage on the grid causes this to vary as shown in Fig. 1*b*. This

current produces a potential drop across the plate resistor R_L which has the same form as the current. This voltage is applied across the grid resistor of the following tube through the coupling **condenser.** However, since a condenser circuit responds only to varying voltages, only the a-c component will appear across the resistor R_{g1} as shown in Fig 1c

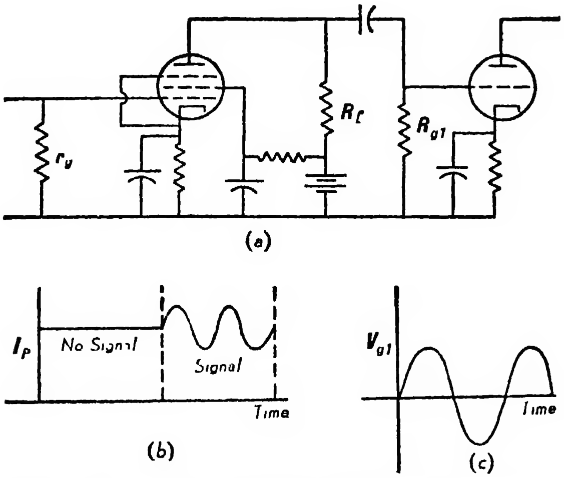


Fig 1 Resistance coupled vacuum-tube amplifier

With proper choice of circuit components the voltage on the second grid is several times that impressed on the first grid The ratio of these voltages is the gain or amplification of the stage.

While this gain varies with frequency, for the middle portion of the operating range it is given by:

$$A = \mu R'_l/(R'_l + R_p)$$

where R_p is the dynamic plate resistance of the tube, μ is the **amplification factor** of the tube, and R'_L is R_l and R_{gl} in parallel **Pentode** tubes are normally used for resistance-coupled amplifiers because of their much greater gain

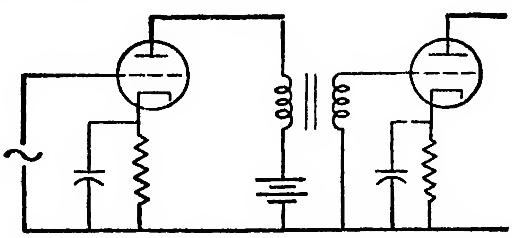


Fig 2 Transformer coupled vacuum-tube amplifier

Fig. 2 shows another method, transformer-coupled, of utilizing the current change in the plate circuit. Here the varying plate current produced by the alternating voltage on the grid produces a voltage across the secondary of the **transformer.** Since the transformer operates only on a-c the voltage across the secondary is a reproduction of that applied to the grid of the first tube The gain of such a stage is very closely given for the middle of its operating range by:

$$A = \mu n$$

where n is the turns ratio of the transformer (secondary/primary) and μ is the amplification factor of the tube Because they give a wider frequency range with transformers than other types of tubes, **triodes** are normally used

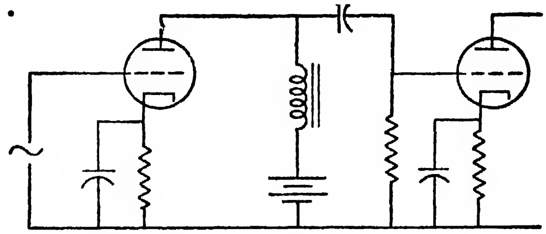


Fig 3 Impedance coupled vacuum-tube amplifier

in such circuits Fig 3 shows a third method of coupling a voltage amplifier This is very similar to the resistance-coupled case but the output voltage drop is across a **choke** or impedance coil This is an impedance-coupled amplifier Since the choke causes only a small voltage drop for d-c, very little of the supply voltage is lost and most of it appears at the plate of the tube, thereby increasing the gain by decreasing the dynamic plate resistance of the tube The frequency response characteristic of this amplifier is usually not as good as for the resistance-coupled type The gain in the middle range is given by

$$A = \frac{\mu 2\pi fL}{\sqrt{R_p^2 + (2\pi fL)^2}}$$

where f is the frequency and L is the inductance of the choke in henries Other symbols are as before

The three circuits shown are commonly used in audio-frequency amplifiers which must operate over a wide frequency range For radio-frequency use the range is much more restricted in terms of its proportion of the mid-frequency value As a consequence such amplifiers can and ordinarily do use tuned circuits for coupling elements Such an amplifier is shown in Fig 4. While there are

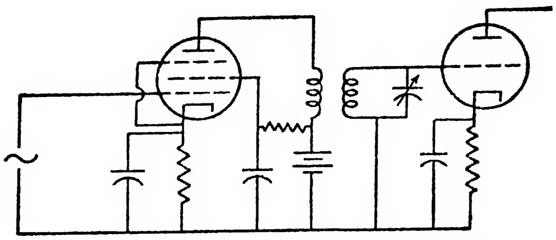


Fig. 4. Tuned vacuum-tube amplifier

many variations of the tuned amplifier, this is typical of those used in the radio-frequency portion of the usual radio receiver. The response of a tuned amplifier varies markedly with frequency and the frequency at which the response is a maximum may be adjusted by varying the condenser. This type amplifier, then, serves as a selective device to differentiate between stations and at the same time serves as an amplifier. The condenser shown is the tuning condenser controlled by the dial on the panel of the ordinary radio set.

For amplifying d-c voltages without the introduction of **modulation** a direct-coupled amplifier must be used since the circuits shown before respond only to alternating voltages. Such an amplifier is shown in Fig. 5. It will

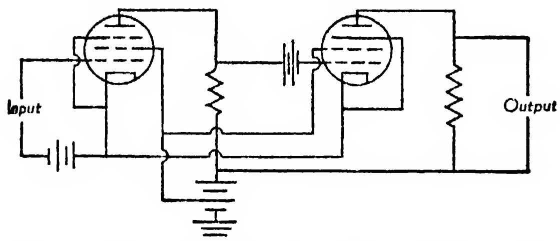


Fig. 5. Direct coupled vacuum-tube amplifier for d-c

be noted that the high voltage of the plate of the first tube would be applied to the grid of the second if it were not for the bucking action of the grid or C battery which must, therefore, be made large enough to give the correct net voltage on the grid. Unless the A, B, and C voltages are carefully regulated, direct-coupled amplifiers are rather unstable and are to be avoided except in cases where nothing else will serve satisfactorily.

The amplifiers discussed above are intended primarily for voltage amplification. However, in many applications it is necessary to get power from an amplifier and so at least the final stage is usually adjusted to give power rather than voltage output. An amplifier so adjusted is called a power amplifier. In radio transmitting circuits or large power audio-amplifiers several stages may be power amplifiers. For this type of service the circuit is adjusted to give as large a current as possible through the load, which has much lower resistance than in voltage amplifiers. The tubes used are somewhat larger as a rule than those of voltage circuits and are specially designed for large current outputs. Power amplifiers are frequently classified as Class A, B, AB or C, depending upon just how they are operated. Class A amplifiers operate about a mean grid bias value such that the output wave is essentially the same as the input wave and the d-c plate current has a constant value (the voltage amplifiers are Class A). A Class B amplifier has the grid bias adjusted so that plate current flows only on the positive half-cycle of the input signal. Class AB is intermediate between A and B. In these three classes a subscript 1 is often used to denote that the grid does not take current, and a subscript 2 to denote that grid current flows. Since AB and B amplifiers using single tubes do not give output waves similar to the input waves they must be operated **push-pull** for audio-frequency work. Class C amplifiers are adjusted so plate current flows for less than a half-cycle of the input signal. They are used exclusively for radio-frequency work where a tuned circuit may be used for the load (See **tank circuit.**) Fig. 6 indicates the relative bias values for the different types of service.

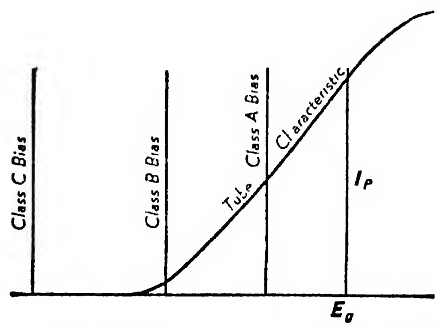


Fig. 6. Bias adjustments for various vacuum-tube amplifier classes

The efficiency becomes better but the distortion worse in the order A, AB, B and C. For audio-frequency work the power amplifiers are normally connected to the load (loud-**speaker**) through a transformer, while in radio-frequency work air-cored transformers and capacitance coupling are common.

AMPLIFIER, VACUUM TUBE, CLASSIFICATION. See **amplifier, class-A, amplifier, class-AB, amplifier, class-B, amplifier, class-C.**

AMPLIFIER, VIDEO-FREQUENCY. A device capable of amplifying such signals as comprise periodic visual presentation.

AMPLIFIER, VOLUME-LIMITING. An **amplifier** containing an automatic device which functions when the input volume exceeds a predetermined level, and so reduces the **gain** that the output volume is thereafter maintained substantially constant, notwithstanding further increase in the input volume. The normal gain of the amplifier is restored when the input volume returns below the predetermined limiting level.

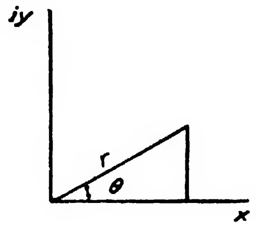
AMPLIFIER, VOLTAGE. An **amplifier** designed for the primary purpose of producing an increase in signal voltage with little or no attention to the available output power of the stage.

AMPLIFIER, WALLMAN. See **amplifier, cascode.**

AMPLIFIER, WIDE-BAND. An **amplifier** having uniform response over many decades of frequency. One example is the video amplifier. (See **amplifier, video-frequency.**)

AMPLISTAT. A trade name applied to self-saturating magnetic amplifier circuits. (See **magnetic amplifier, self-saturating.**)

AMPLITUDE. (1) If a **complex number** is represented in polar coordinates it becomes $r(\cos\theta + i\sin\theta)$ and the angle θ is the amplitude, argument, or phase of the number. (See **de Moivre theorem.**) The term is also used to designate a parameter occurring in **elliptic functions** and **integrals.** (2) The crest or maximum value of a periodic (or specifically a simple harmonic function of space or time) or, more generally, any parameter that when changed, merely represents a change in scale factor. In amplitude-modulation systems, this quantity becomes a function of time, and its instantaneous value is of importance, but it is still referred to as the amplitude.



AMPLITUDE COMPARISON. The process of indicating the time at which two waveforms reach the same **amplitude.** It may also be considered to be the method of determining the abscissa of a waveform, given its ordinate.

AMPLITUDE DISCRIMINATOR. A circuit which performs an **amplitude comparison.** In addition, the sense and magnitude of the inequality of the amplitudes may be obtained

AMPLITUDE DISTORTION. A type of **distortion** that occurs in an **amplifier** or other device when the amplitude of the output is not exactly a linear function of the input amplitude. (See also **amplitude-frequency distortion; waveform-amplitude distortion;** and **harmonic distortion.**)

AMPLITUDE FADING. See **fading, amplitude.**

AMPLITUDE-FREQUENCY DISTORTION. Distortion due to an undesired amplitude-frequency characteristic. The usual desired characteristic is flat over the frequency range of interest. Amplitude-frequency distortion is sometimes called amplitude distortion or frequency distortion.

AMPLITUDE (INITIAL). The maximum displacement from a reference point of a periodic function. The periodic function can describe the motion of a pendulum point, the motion of a point on a spring or of a point on a mechanical system which is performing oscillatory motion or may represent the motion of a wave in a medium. (Cf. **harmonic motion.**)

AMPLITUDE LIMITER. See **limiter.**

AMPLITUDE MODULATION (AM). See **modulation, amplitude.**

AMPLITUDE-MODULATION NOISE LEVEL. See **noise level, amplitude-modulation.**

AMPLITUDE-MODULATED TRANSMITTER. See **transmitter, amplitude-modulated.**

AMPLITUDE OF COMPLEX NUMBER (ARGUMENT). A complex number $z = x + iy$ can be written as $z = r(\cos\theta + i\sin\theta)$. θ is called the amplitude or argument of z.

AMPLITUDE OF A GENERALIZED SINUSOIDAL QUANTITY. The amplitude of a generalized sinusoidal quantity for any value of the independent variable is the value of the modifying function for that particular value of the independent variable. If

$$y = f_0(x) \sin (\omega x + a)$$

the amplitude of y for $x = x_1$ is $f_0(x_1)$.

AMPLITUDE OF A SIMPLE SINUSOIDAL QUANTITY. The amplitude of a simple sinusoidal quantity is the largest value that the quantity attains. If

$$y = A \sin (\omega x + a),$$

then A is the amplitude.

AMPLITUDE OF OSCILLATION. The peak value of a sine wave is called its amplitude. By extension, a nearly sinusoidal wave, such as a damped-sine wave, or a slowly amplitude modulated wave, written in the form

$$x = F(t) \sin (\omega t + \phi)$$

is said to have the (time-varying) amplitude $F(t)$.

AMPLITUDE, PEAK-TO-PEAK (DOUBLE AMPLITUDE). Of an oscillating quantity, the difference between extremes of the quantity.

AMPLITUDE RESONANCE. See **resonance, frequency of.**

AMPLITUDE SELECTION. See **amplitude separation,** and **clipper circuit.**

AMPLITUDE SEPARATION. The process of separating all values of a wave greater or less than a given **amplitude,** or those lying between two amplitudes.

AMPLITUDE VERSUS FREQUENCY RESPONSE CHARACTERISTIC. The variation with frequency of the **gain** or **loss** of a device or a system.

AMU. The atomic mass unit, a unit of mass equal to one-sixteenth the mass of the atom of oxygen of mass number 16.

$$1 \text{ amu} = 1.657 \times 10^{-24} \text{ g.}$$

In terms of energy, 1 amu = 931 mev = 1.49×10^{-3} ergs.

ANABATIC WIND. A wind blowing uphill. In general, anabatic winds refer to winds originating in connection with surface heating, such as a breeze blowing up a valley when the sun warms the ground.

ANALOG COMPUTER. A physical system together with means of control for the performance of measurements (upon the system) which yield information concerning a class of mathematical problems. In an analog computer quantities are represented without explicit use of a language.

ANALYTIC. A function $f(z)$ of the **complex variable** $z = x + iy$ is **analytic** at a point on the z-plane if the function and its first derivative are finite and single-valued in the neighborhood of the point. If this property applies to all points within a given region of the complex plane, $f(z)$ is an analytic function throughout the region. Any point at which the derivative fails to exist is a **singularity** or a **singular point** of the function.

Equivalent definitions of an analytic function are: (1) it must satisfy the **Cauchy-Riemann equations** or **Laplace's equation;** (2) it is analytic only if it may be represented by a **convergent power series** in some neighborhood of the given point.

Other words often used in place of analytic are **holomorphic, meromorphic, monogenic, uniform, regular.**

An analytic function of a **real variable** may be defined in a similar way.

ANALYTIC CONTINUATION. Calculation of the **analytic** function over some domain from precise definition of the function over a smaller domain.

ANALYTICAL GAP. The region between the two electrodes of the source in emission spectroscopic analysis; also called the electrode gap.

ANALYZER. (1) The **nicol prism** (or other device which passes only that component of light which is polarized in a particular plane) which is placed in the **eyepiece** of a **polariscope** or similar instrument. (2) A volt-ohm-milliammeter test instrument.

ANASTIGMAT. A **compound lens** combination corrected so that both **astigmatism** and the **curvature of the field** are largely eliminated over a considerable area in the **image plane.**

ANCHOR RING. Also called a **torus,** it is a surface which has the shape of a doughnut with a hole in it. It can be generated as a surface of revolution by rotating the circle

$$(y - b)^2 + z^2 = a^2$$

around the Z-axis. Its equation, when rationalized, is of the fourth degree

$$(x^2 + y^2 + z^2 + b^2 - a^2)^2 = 4b^2(x^2 + y^2).$$

ANDERSON BRIDGE. See **bridge, Anderson.**

ANECHOIC ROOM. A room in which sound reflections from the boundary surfaces have been reduced to a negligible amount.

ANELASTICITY (OR INTERNAL FRICTION). In general, any deviation from the ideal behavior postulated by classical **elasticity** theory (where the strain is proportional to the applied stress and follows instantaneously upon its application). The term is applied particularly to those phenomena associated with the damping of elastic waves in solids. Numerous causes are known for these effects, such as **thermal diffusion,** motion of **grain boundaries,** diffusion of **twin boundaries, atomic solution diffusion,** etc. The damping associated with a given process depends strongly on the frequency of the elastic wave.

ANEMOGRAPH. Instrument used for recording wind velocity.

ANEMOMETER. An apparatus for measuring gas velocity, or sometimes pressure, especially that of air.

ANEMOMETER, CUP. An **anemometer** consisting of a set of three or four hemispherical or conical cups mounted on a wheel whose axle is vertical. When the wind blows it forces the cups and the wheel to rotate; the wind velocity is related to the total number of rotations over a short period of time. Various types of counters are used to determine the rotations per min or per sec.

ANEMOMETER, PLATE. An **anemometer** consisting of a simple plate mounted in such a manner that the wind blows against it, deflecting it in the direction toward which the wind is blowing. A pointer or scale mounted along the plate measures the deflection of the plate, which can be correlated to the wind velocity.

ANEMOMETER, PRESSURE-TUBE. An **anemometer** employing the difference in static and dynamic pressure in a wind blowing across a tube mounted with its opening directly into the wind.

ANEMOSCOPE. An instrument actuated by a wind vane, and showing wind direction on a calibrated scale.

"ANGELS." Radar reflections in the lower atmosphere, usually of short duration, and observed most frequently below 3000 feet. Since, in most cases, the object causing the reflection was not visible, the object was called an "angel." Experiments have proved that, in many cases, these reflections are due to insects or birds.

ANGLE. The figure obtained by drawing two straight lines from a point. In trigonometry, an angle measures the rotation of one straight line, the terminal line, about a fixed point on an initial line. It is positive if the direction of rotation is counterclockwise. If the magnitude of the angle equals 2π **radians,** it is called a perigon angle and such an angle, divided into 360 equal parts, has a magnitude of 360 degrees (360°). A right angle equals 90° or $\pi/2$ radians; a straight angle, 180° or π radians; an acute angle is less than 90°; an obtuse angle, greater than 90° (but frequently limited to one less than 180°). (See also **Euler angles; angle, dihedral; angle, solid; triangle, spherical.**)

ANGLE, DIFFRACTION. The angle between the direction of an incident beam of light and any resulting diffracted beam. (See **diffraction.**)

ANGLE, DIHEDRAL. The angle between two planes. The dihedral angle is zero if the planes are parallel. If the direction cosines of perpendiculars to two planes are λ,μ,ν and λ',μ',ν' the dihedral angle between the planes is given by

$$\cos\theta = \lambda\lambda' + \mu\mu' + \nu\nu'$$

ANGLE MODULATION. See **modulation, angle.**

ANGLE OF ARRIVAL. The angle between the line of propagation of a radiowave and the earth's surface at the point of reception.

ANGLE OF BEAM. In a directional antenna system, the angle which encloses the greater part of the transmitted or received energy.

ANGLE OF DEFLECTION. In cathode-ray devices, the angle through which the beam is deflected.

ANGLE OF DEPARTURE. The angle between the line of propagation of a radiowave and the earth's surface at the point of transmission.

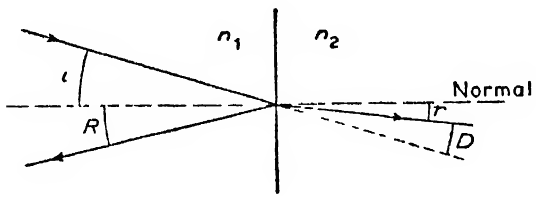
ANGLE OF DEVIATION. The angular change in direction of a ray of light, or other electromagnetic radiation, upon entering another medium (See **angle of incidence.**)

ANGLE OF DEVIATION, MINIMUM. See **minimum angle of deviation.**

ANGLE OF DIP. See **dip-needle.**

ANGLE OF DIVERGENCE. The maximum **angle of deflection** experienced by electrons in an electron beam due to **debunching.**

ANGLE OF INCIDENCE. The angle between a ray of light striking a surface and the normal to that surface, as shown in the accompanying figure



$n_2 > n_1$

where i is the angle of incidence, R is the angle of reflection, r is the angle of refraction, D is the angle of deviation, n_1 is the index of refraction of the medium from which the light is incident upon the surface, and n_2 is the index of refraction of the medium into which the light is refracted from the surface (See the **Snell law.**)

ANGLE OF PRINCIPAL AZIMUTH. Circularly-polarized light incident on a metallic surface at the **angle of principal incidence** will be reflected as plane-polarized light with its plane of vibration making an angle of principal azimuth with the **plane of incidence.**

ANGLE OF PRINCIPAL INCIDENCE. Plane-**polarized light** incident at an angle upon a metallic surface becomes in general elliptically-polarized There is one particular **angle of incidence,** called the principal angle of incidence, for which one axis of the ellipse lies in the **plane of incidence.**

ANGLE OF REFLECTION. The angle between a ray of light and the normal to a surface. This angle and the **angle of incidence** are in the same plane. They are related by the equality $R = i$.

ANGLE OF REFRACTION. The angle between a ray of light after **refraction** at an interface between two media and the normal to the interface This angle and the **angle of incidence** are in the same plane. (See the **Snell law.**)

ANGLE OF REPOSE. The maximum angle with the horizontal at which an object on an inclined plane will retain its position without tending to slide. The tangent of the angle of repose equals the coefficient of static friction. (Cf. **friction (coefficient of static).**)

ANGLE OF SLIP. (1) The angle included between the direction of the applied force and the surface of **shear** during the **plastic flow** of a solid body. (2) The **angle of repose.**

ANGLE OR PHASE OF SINE WAVE. The measure of the progression of the wave in time or space from a chosen instant or position In the expression for a sine wave, the angle or phase is the value of the entire linear function. In the representation of a sine wave by a rotating vector, the angle or phase is the angle through which the vector has progressed.

ANGLE, SOLID. Consider a small cone with a base of area dS and a vertex at a fixed point P. This cone will cut out an area $d\sigma$ on a sphere of radius r with center at P. The **solid angle** subtended by dS at P is defined as $d\omega = d\sigma/r^2$. It is numerically equal to the area cut out by the same cone on a sphere of unit radius at the same point P. The unit used for measuring a solid angle is the **steradian.**

ANGLE VARIABLE. In classical mechanics, the dynamical variable w conjugate to the **action variable** J, and thus defined only for periodic motion. For such motion of frequency ν, $w = \nu t +$ const.

ÅNGSTROM COEFFICIENT. The coefficient A in Ångstrom's formula for the scattering coefficient for dust in the atmosphere.

$$S = A\lambda^{-B}$$

in which λ is wavelength and B depends on the particle size.

ÅNGSTROM UNIT. The Ångstrom unit equals 10^{-8} centimeters. Visible light has a wave length of a few thousand (4000–7500) Ångstroms. The diacritical mark over the first letter is frequently omitted.

ANGULAR ACCELERATION. See **acceleration, angular.**

ANGULAR DEVIATION LOSS. See **deviation loss, angular.**

ANGULAR DISTRIBUTION. In nuclear physics, the distribution in angle, relative to an experimentally specified direction, of the intensity of particles or photons resulting from a nuclear or an extra-nuclear process. Commonly, the specified direction is that of an incident beam, and the angular distribution is that of particles which are scattered or are the products of nuclear reactions. In such cases, the angular distribution in the **laboratory system** will depend upon the energy of the incident particles. Alternatively, the specified direction might be that of an applied field, or a direction of polarization, or the direction of emission of an associated radiation.

ANGULAR FREQUENCY. See **frequency, angular.**

ANGULAR MAGNIFICATION. The ratio of the tangent of the angle with the optical axis made by a ray upon emergence from an optical instrument to the tangent of the angle for the conjugate incident ray.

ANGULAR MOMENTUM. The product of the **moment of inertia** of a rotating body or system of bodies, as measured about any axis of rotation, by the angular velocity about that axis. Angular momentum is a **conserved quantity,** which remains constant in any isolated system. It is a **vector** quantity, having the direction of the axis of rotation and a sense such that the vector points toward the observer if the rotation is counterclockwise as seen by him. (See also **torque.**)

ANGULAR MOMENTUM (ATOMIC AND NUCLEAR PHYSICS). The angular momentum, or moment of momentum, of an elementary particle or system of such particles that either (a) spins about an axis or behaves as though it spins about an axis, or (b) revolves in an orbit or behaves as though it revolves in an orbit. For an elementary particle, the angular momentum associated with axial rotation is called the intrinsic angular momentum, or spin. When a nucleus is considered as a single particle, its total angular momentum is also referred to as its spin. For an elementary particle, the component in a particular direction of both kinds of angular momentum is quantized; the quantum of spin angular momentum is $\frac{1}{2}\hbar$, and the quantum of orbital angular momentum is $\hbar$.

ANGULAR MOMENTUM OPERATORS. Three operators $\mathbf{J} = J_x, J_y, J_z$ such that $J_xJ_y - J_yJ_x = iJ_z$ and the equations obtained from this by cyclic change. Two examples are the orbital angular momentum operator $\mathbf{L} = -i\mathbf{r} \times \nabla$ and the **Pauli spin operators.**

ANGULAR VELOCITY. See **velocity, angular.**

ANHARMONIC MOTION, CLASSICAL. The motion of an **anharmonic oscillator** as treated by classical (non-quantum) mechanics.

ANHARMONIC OSCILLATOR. An oscillator in which the restoring force, mechanical or electrical in general, does not vary linearly with the displacement of the system from its equilibrium position.

ANHARMONIC TERMS. Terms in the expression for the potential energy of a molecule or a solid which are cubic or of higher power in the displacements of the particles. They are responsible for **thermal expansion** and for thermal resistivity through the **phonon-phonon interaction.**

ANHARMONICITY. (1) The term mechanical anharmonicity refers to a mechanical vibration in which the **restoring force** acting on the system does not vary linearly with the displacement of the system from its **equilibrium** position. (2) A phenomenon to which the term electrical anharmonicity is applied occurs in the calculation of the intensities of **infrared bands.** This phenomenon is a departure of the variation of **dipole moment** with internuclear distance from a strictly linear relationship.

ANION. An **ion** which deposits on the **anode;** that portion of an electrolyte which carries

the negative charge and travels against the conventional direction of the electric current in a cell. Within the category of anions are included all the nonmetallic ions and the acid radicals, as well as the hydroxyl ion. In electrochemical reactions they are designated by the minus sign placed above and behind the symbol, i.e., Cl^- or $SO_4^=$, the number of minus signs indicating the magnitude, in electrons, of the electrical charge carried by the anion.

In **electrolysis,** the anode is positive, and the anion is attracted. In a **battery,** it is the deposition of negative anions that makes the anode negative.

ANIONIC CURRENT. That portion of the electric current carried by the anions.

ANISEIKON. An electronic flow-detector.

ANISEIKONIA. A term for unequal imagery. By imagery is meant not the retinal image, but that which reaches consciousness as a perception. (See **anisopia.**)

ANISODESMIC STRUCTURE. A type of **ionic crystal** in which some of the **ions** tend to form tightly bound groups, e.g., nitrate, chlorate, etc.

ANISOPIA. Unequal vision in the two eyes producing unequal imagery. Anisopia can be either inherently existing or artificially produced.

ANISOTROPIC. Nonisotropic, and thus having different optical or other physical properties in differing directions. Wood and calcite crystals are anisotropic, while fully-annealed glass and, in general, fluids at rest are isotropic.

ANISOTROPIC MEDIUM. Any medium whose properties are different in different directions.

ANISOTROPY. Any property of a material which results from its **anisotropic** nature.

ANISOTROPY, FERROMAGNETIC. See discussion of **crystalline anisotropy energy.**

ANNEALING. The process of holding a solid material at an elevated temperature for some length of time in order that any metastable condition (e.g., frozen-in **strains, dislocations, vacancies,** etc.) may go into thermodynamic equilibrium. This may result in **recrystallization** and **polygonization** of cold-worked samples.

ANNIHILATION. (1) A process in which a pair of anti-particles meet and convert spontaneously into one or more photons; it is the inverse of **pair production.** The commonest example is the annihilation of an electron and a positron, the rest masses of which are converted into (usually) two 0.511-mev photons according to the principle of **mass-energy equivalence.** (2) The conversion of **rest mass** into electromagnetic radiation.

ANNIHILATION FORCE. Contribution to the force between an electron and a positron arising from the fact that these particles may virtually annihilate each other, thereby making the charges less effective and the attraction less. This raises the 1^3S level of **positronium** by an amount $\frac{1}{4}\alpha^4 mc^2$ $(\alpha = \frac{1}{137})$.

ANNIHILATION RADIATION. Electromagnetic radiation produced by the union, and consequent annihilation, of a **positron** and an **electron.** Each such annihilation usually produces two, rarely one or three, photons. These photons have properties identical with those of γ-rays, and accompany the decay of all positron-emitting radioactive substances. A positron and an electron are most likely to unite when their relative velocity is small, hence the energy available for the annihilation radiation will be that of the rest-masses of the electron, $2m_ec^2$ [= 1.02 mev], and the process will usually result in the production of two oppositely-directed photons, each of energy 0.51 mev.

ANODE. The electrode via which current enters a device. The anode is the positive terminal of an electroplating cell, but the negative terminal of a battery. The term anode is customarily used for any thermionic tube electrode operated at an appreciably-positive potential.

ANODE BREAKDOWN VOLTAGE (OF A GLOW-DISCHARGE COLD-CATHODE TUBE). The anode voltage required to cause conduction across the **main gap,** with the **starter gap** not conducting, and with all other tube elements held at cathode potential before breakdown.

ANODE CURRENT. See **electrode current.**

ANODE FALL. In a **gas discharge tube,** the fall of potential (it may be either positive, zero or negative) between the **positive column** and the anode.

ANODE, HOLDING. A small auxiliary anode in a mercury-pool **rectifier** such as an **ignitron** or **excitron.** It is supplied with d-c, and has the function of keeping a cathode spot energized during intervals when the main anode current is zero.

ANODE SHEATH. In a **gas discharge tube,** the electron boundary which exists between the **plasma** and anode when the current demanded by the anode circuit is larger than the random electron current at the surface of the anode. The **anode fall** is positive for this condition.

ANODE RAYS. Among the positively charged particles recognizable in a (so-called) **vacuum tube,** and mixed with the ionized molecules and atoms of the rarefied gas, are sometimes found ions which are traceable to the metallic anode or to impurities in it or upon its surface. The anode may be oxidized or have films or patches of metallic salts upon it which, in the operation of the tube, in some manner not fully understood, yield ions of the metal. If the anode is treated with alkali or alkaline-earth salts or oxides and strongly heated, very copious positive emission may result, serving as a convenient source of positive rays.

ANODE SUPPLY VOLTAGE. See **plate supply.**

ANODE VOLTAGE. See **electrode voltage.**

ANODE VOLTAGE DROP (OF A GLOW-DISCHARGE COLD-CATHODE TUBE). The main gap voltage drop after conduction is established in the **main gap.**

ANODE VOLTAGE, PEAK FORWARD. The maximum instantaneous anode voltage in the direction in which the tube is designed to pass current.

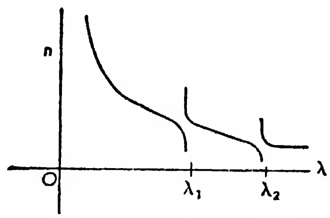
ANODE VOLTAGE, PEAK INVERSE. The maximum instantaneous anode voltage in the direction opposite to that in which the tube is designed to pass current.

ANODIZE. To place a protective film on a metal surface by electrolytic or chemical action. Aluminum and magnesium parts of electronics equipment are frequently anodized.

ANOLYTE. The liquid near the **anode** during **electrolysis.**

ANOMALOUS ATOMIC SCATTERING METHOD. A proposed method of **x-ray analysis** in which the variation with the x-ray wavelength of the **scattering power** of certain atoms is to be exploited.

ANOMALOUS DISPERSION. Ordinarily the **refractive index** n of a medium decreases with increasing wavelength λ (see **dispersion**). It often happens, however, that in the immediate vicinity of a certain wavelength λ_1 there is a break or discontinuity in the dispersion



Variation of refractive index with wavelength, illustrating anomalous dispersion

curve and the usual rule may be locally reversed (see figure). In some cases there are several such points, $\lambda_1, \lambda_2, \lambda_3, \cdots$. These discontinuities correspond to lines or bands in the **absorption spectrum** of the medium. In the Sellmeier dispersion formula,

$$n = 1 + \frac{A\lambda^2}{\lambda^2 - \lambda_1^2} + \frac{B\lambda^2}{\lambda^2 - \lambda_2^2} + \cdots,$$

the several fractional terms make provision for the respective discontinuities The absorption wavelengths $\lambda_1, \lambda_2 \cdots$ and the constants $A, B, \cdots$ must be determined experimentally. If there is pronounced absorption and anomalous dispersion in the visible range, the medium appears colored, as illustrated by transparent **dyes.** (See also **Hartmann formula.**)

ANOMALOUS MAGNETIC MOMENT (ELECTRON). Contribution $e^3/4\pi mc^2$ to the magnetic moment of the electron arising from radiative corrections to the value $e\hbar/2mc$ derived from the unquantized **Dirac electron theory.**

ANOMALOUS OR DISPLACED TERMS. Spectral terms forming part of a group for which the limiting terms (corresponding to the

ionizing potential in the normal spectra) have negative values.

For example, a complete energy level diagram for calcium shows two such sets of levels, marked 3d and 4p, which are located above the limit for the normal terms of the spectrum.

ANOMALY OF STRONG ELECTROLYTES. See **electrolytes, anomaly of strong.**

ANOTRON. A cold-cathode, glow-discharge diode. The cathode frequently may be of sodium, while the anode is composed of copper.

ANTENNA. In the process of radio communication the power generated in the **transmitter** must be projected or radiated into space and at the **receiver** some of this radiated energy must be abstracted from the passing radio wave and fed into the receiver proper. It is the antenna which radiates the power at the transmitter and which picks up the signal at the receiver. The antenna form ranges from a simple short length of wire for the receiver to an elaborate array of wires or steel towers for large transmitters. When alternating voltage of a high frequency is connected to a conductor which is open at the end a corresponding high-frequency a-c will flow in the conductor and return to the voltage source through the capacitance between the conductor and the rest of the circuit. This rapid a-c causes energy to be radiated into space from the conductor. This energy travels out from the conductor and does not return. The conductor in this case is the antenna (of course the various connecting wires of the transmitter also have high-frequency a-c and hence will radiate to some extent but very inefficiently). The efficiency with which an antenna radiates is determined by its length and configuration, and its location with respect to the ground, surrounding objects, etc. In general, better radiation is obtained when the antenna length is an appreciable part of a wavelength of the radio signal. Thus they are usually such values as quarter-wave, half-wave, etc.

ANTENNA, ACHROMATIC. An **antenna** whose characteristics are uniform over some desired band of frequencies.

ANTENNA, ADCOCK. A pair of vertical **antennas** separated by a distance of one-half wavelength or less and connected in **phase opposition** to produce a radiation pattern having the shape of a figure of eight.

ANTENNA, ALFORD SLOTTED TUBULAR. A horizontally-polarized antenna developed for FM broadcast work. It consists of a sheet of metal bent into the form of a cylinder which is not quite closed, hence a straight narrow slot extends the full length of the cylinder or tube. It is so dimensioned that the distribution of potential across the slot has very nearly the same phase throughout the entire length of the slot. The currents produced flow in horizontal circles around the cylinder so that the latter operates something like a stack of small, in-phase loops.

ANTENNA, APERIODIC. A non-resonant, and thus frequency-insensitive antenna.

ANTENNA ARRAY. A system of **antennas** coupled together for the purpose of obtaining directional effects.

ANTENNA ARRAY, APERTURE OF THE. That portion of a plane surface near the **antenna,** perpendicular to the maximum direction of radiation, through which the major portion of the radiation passes.

ANTENNA ARRAY, BINOMIAL. A type of broadside array in which the radiation pattern will contain a single lobe (or two lobes if the pattern is bidirectional). All of the antennas are fed in the same phase, they are uniformly spaced at half-wavelength intervals, and the relative current amplitudes in various elements in the array follow the numbers of the binomial expansion. (See **antenna array, broadside.**)

ANTENNA ARRAY, BROADSIDE. Parallel antenna elements with currents in phase may be combined to form a broadside array, so named because the direction of maximum radiation is broadside to the plane containing the antennas. The resulting radiation pattern has circular symmetry about the line of antennas as an axis.

ANTENNA ARRAY, CLOSE-SPACED. An array in which the spacing of the elements is less than ½ wavelength.

ANTENNA ARRAY, CONTINUOUS LINEAR. An infinite number of infinitesimally spaced sources. Some dielectric antennas (see **antenna, dielectric**) and leaky-pipe antennas (see **antenna, leaky-pipe**) belong to this general class.

ANTENNA ARRAY, END-FIRE. Parallel antenna elements with currents 180° out of phase, which radiate the greater part of their energy along the line of the antennas.

ANTENNA ARRAY. LINEAR. An **antenna array** whose elements are equally spaced along a straight line.

ANTENNA, ARRAY OF ARRAYS. A number of similar **antenna arrays** each having a moderate amount of directivity may be arrayed to form an array of arrays.

ANTENNA, BANDWIDTH OF. The range of frequencies within which the performance of an antenna, in respect to some characteristic, conforms to a specified standard.

ANTENNA, BEVERAGE. See **antenna, wave.**

ANTENNA, BICONICAL. An **antenna** formed by two conical conductors, having a common axis and vertex, and excited at the vertex. When the vertex angle of one of the cones is 180°, the antenna is called a **discone.**

ANTENNA, BROADBAND. An **antenna** which will function satisfactorily over a bandwidth in the order of 10 per cent or more of its center frequency.

ANTENNA, "BUPS." A 10 cm dipole array which is non-directional in azimuth. Maximum radiation occurs at low vertical angles. Used for beacon service.

ANTENNA, CAGE. An antenna in which the radiating members are parallel rods arranged in a cylindrical fashion.

ANTENNA, CAPACITOR. An **antenna** in which the capacitance between two conductors or systems of conductors is the essential characteristic. A dielectric antenna (See **antenna, dielectric.**)

ANTENNA, CHEESE. A cylindrical parabolic reflector enclosed by two plates perpendicular to the cylinder, so spaced as to permit the propagation of more than one **mode** in the desired direction of **polarization.** It is fed on the focal line.

ANTENNA, CHIREIX-MESNY. A high-frequency, directive **antenna** in which each dipole element forms one side of a square. Cophased vertical and horizontal current components flow in the diagonals. A reflecting sheet which is a duplicate of the driven element is spaced one-quarter wavelength to the rear. The radiation pattern is a unidirectional beam, broadside to the plan of the radiators.

ANTENNA, CIRCULAR. Essentially a folded dipole antenna (see **antenna, folded dipole**) bent into a circle.

ANTENNA, "CLOVERLEAF." An **antenna** for transmission or reception of horizontally-polarized radiation in a non-directional pattern in a plane normal to the axis of the antenna. Its name arises from the fact that it is comprised of a cluster of four half-wave, curved, radiating elements arranged in the pattern of a four-leaf clover.

ANTENNA, COAXIAL. An **antenna** comprised of a quarter wavelength extension to the inner conductor of a **coaxial line,** and a radiating sleeve which, in effect, is formed by folding back the outer conductor of the coaxial line for approximately one-quarter wavelength.

ANTENNA(S), COLINEAR COAXIAL. Coaxial antennas arranged in a colinear array. (See **antenna, coaxial** and **antenna, colinear.**)

ANTENNA, COLINEAR OR FRANKLIN. An **antenna** consisting of a number of half-wave dipoles (see **antenna, dipole**) placed end-to-end, all operating in phase.

ANTENNA, COMBINED V AND H. A combined **loop** and vertical radiator which radiates equal-strength horizontal and vertical field components.

ANTENNA, CONICAL. A wide-band **antenna** in which the driven element or elements are conical in shape (See **antenna, biconical.**)

ANTENNA, (HOLLOW) CONICAL. A biconical antenna (see **antenna, biconical**) in which the spherical end-caps for the conical sections have been left off.

ANTENNA, COSECANT-SQUARED. A type of radar **antenna** which provides constant field strength at a given altitude over an appreciable range. So-called because the power in the antenna pattern on one-way transmission decreases at a rate proportional to the square of the cosecant of the elevation angle. This radiation-pattern may be approximated by using a paraboloidal reflector with several

radiators arranged in a line perpendicular to the axis.

ANTENNA CROSS TALK. A measure of undesired power transfer through space from one antenna to another. Numerically, antenna cross talk is the ratio of the power received by one antenna to the power transmitted by the other, usually expressed in **decibels.**

ANTENNA COUNTERPOISE. One or more wires stretched beneath an **antenna,** but elevated above, and insulated from, the earth. The antenna circuit is completed through the capacitance of the counterpoise to ground. This system has application where a satisfactory connection to ground is not possible or practical. In high-frequency systems, the antenna plus counterpoise is sometimes called the ground-plane antenna.

ANTENNA, (HOLLOW) CYLINDRICAL. An **antenna** containing hollow cylinders as radiating elements. The dipole antenna frequently contains hollow-cylindrical elements in order that desired impedance-matching and bandwidth characteristics may be obtained (See **antenna, dipole.**)

ANTENNA, CUBICAL. An array (see **antenna array**) of elements arranged in a cubical formation.

ANTENNA, DIAMOND. The name sometimes applied to the rhombic antenna (See **antenna, rhombic.**)

ANTENNA, DIELECTRIC. An **antenna** which employs a **dielectric** as the major component in producing the required **radiation pattern.**

ANTENNA DIPLEXER. A circuit configuration which will permit two transmitters (the video and aural transmitters of a television station as an example) to transmit simultaneously from the same **antenna** without interaction.

ANTENNA, DIPOLE. A straight radiator, usually fed in the center, and producing a maximum of radiation in the plane normal to its axis. The length specified is the over-all length. Common usage in microwave antennas considers a dipole to be a metal radiating structure which supports a line current distribution similar to that of a thin straight wire, a half-wavelength long, so energized that the current has two **nodes,** one at each of the far ends.

ANTENNA, DIRECTIONAL. An **antenna** having the property of radiating or receiving radio waves more effectively in some directions than others.

ANTENNA DIRECTIVE GAIN. See **antenna power gain.**

ANTENNA, DISCONE. An **antenna** of a disk and a cone whose apex approaches and becomes common with the outer conductor of the coaxial feed at its extremity. The center conductor terminates at the center of the disk, which is perpendicular to the axis of the cone. Its most important characteristic is its ability to operate over a very wide bandwidth without a substantial change of input impedance or radiation pattern. The radiation pattern is omnidirectional in a plane perpendicular to the axis of the cone.

ANTENNA, DOUBLET. Sometimes referred to as a half-wave dipole or Hertz antenna, it is center-fed and has an over-all length of approximately one-half a wavelength. (See **antenna, dipole.**)

ANTENNA, DUMMY. A device which has the necessary impedance characteristics of an antenna and the necessary power-handling capabilities, but which does not radiate or receive radio waves. In receiver practice, that portion of the impedance not included in the signal generator is often called "dummy antenna."

ANTENNA EFFECT. (Old usage.) In a loop antenna (see **antenna, loop**), any spurious effect resulting from the capacitance of the loop to ground.

ANTENNA EFFECTIVE HEIGHT. The effective antenna height h is found from the following relationship

$$h = \frac{\epsilon d}{0.2\omega I}$$

where h is the effective height in meters, ϵ is the measured field intensity in microvolts per meter, d is the distance in kilometers from antenna to point of ϵ measurement, ω is the angular frequency in kiloradians per second, I is the antenna current in amperes at point of energization.

ANTENNA EFFECTIVE RESISTANCE. See **antenna resistance.**

ANTENNA ELECTRICAL HEIGHT (LENGTH). The actual length of the **antenna** in terms of wavelengths or fractions thereof. Applicable only in systems with sinusoidal current distribution.

ANTENNA, FANNED-BEAM. A unidirectional **antenna** so designed that transverse cross sections of the major **lobe** are approximately elliptical.

ANTENNA FIELD GAIN. The ratio of the effective free space **field intensity** produced at one mile in the horizontal plane expressed in millivolts per meter for 1 kilowatt antenna input power to 137.6 mv/m.

ANTENNA, FISHBONE. An **antenna** consisting of a series of coplanar elements arranged in collinear pairs, loosely coupled to a balanced transmission line.

ANTENNA, FLAGPOLE. The name sometimes applied to the coaxial antenna (see **antenna, coaxial**) because of its flagpole-like appearance.

ANTENNA, FOLDED DIPOLE. An **antenna** composed of two parallel, closely spaced dipole antennas (see **antenna, dipole**) connected together at their ends with one of the dipole antennas fed at its center.

ANTENNA, FRANKLIN. See **antenna, colinear.**

ANTENNA, GAIN OF. (Old usage.) The measured gain of one transmitting or receiving **antenna** over another is the ratio of the signal power one antenna produces at the receiver input terminals to that produced by the other, the transmitting power level remaining fixed.

ANTENNA, GROUND-PLANE. See **antenna, counterpoise.**

ANTENNA, GROUND SYSTEM OF. That portion of an **antenna,** closely associated with and including an extensive conducting surface, which may be the earth itself.

ANTENNA HEIGHT ABOVE AVERAGE TERRAIN. The average of the **antenna** heights above the terrain from two to ten miles from the antenna. (In general a different antenna height will be determined by each direction from the antenna. The average of these various heights is considered as the antenna height above the average terrain.)

ANTENNA, HELICAL. An **antenna** used where circular polarization is required. The driven element consists of a helix supported above a ground plane. If the circumference of one turn is approximately one wavelength the radiation is said to be in the axial mode and is directed predominately along the axis of the helix. In this mode the antenna has good efficiency and relatively broad bandwidth.

ANTENNA, HERTZ. See **antenna, doublet.**

ANTENNA, HORN-TYPE. A flared, open extension of a **waveguide** which may be dimensioned to provide **impedance match** between the waveguide and free space as well as directional characteristics over a comparatively wide frequency-range.

ANTENNA, IMAGE. An **antenna** located close to the earth's surface (assumed to be a perfectly-conducting plane) transmits a direct ray, and a ray reflected from the earth's surface. It is convenient to represent the reflected ray as originating from an image antenna identical to the original, and located inside the earth by a distance equal to the height of the original above the earth.

ANTENNA INPUT RESISTANCE. See **antenna resistance.**

ANTENNA, ISOTROPIC (UNIPOLE). A hypothetical **antenna** radiating or receiving equally in all directions. A pulsating sphere is a unipole for sound waves. In the case of electromagnetic waves, unipoles do not exist physically, but represent convenient reference antennas for expressing directive properties of actual antennas.

ANTENNA, J. A half-wave antenna, end-fed by a parallel-wire, quarter-wave section having the configuration of a J.

ANTENNA, LEAKY-PIPE. External radiation is produced by providing a hole or slot in a **waveguide** propagating electromagnetic power. Proper choice of the size and location of a series of holes in the waveguide may lead to quite directional radiation-patterns.

ANTENNA, LENS. To satisfy high directivity requirements, a lens is often placed in front of another radiator such as a **dipole** or

horn. In much the same manner as an optical lens focuses light waves, these microwave lenses focus the high-frequency energy into a sharp beam.

ANTENNA, LENS (ARTIFICIAL DIELECTRIC OF). The function of the dielectric is to delay the portion of the **wavefront** going through the middle of the lens. These lens are sometimes called delay lenses for this reason. Because of their weight, dielectric lenses made from such materials as polystyrene are not usually used in microwave lenses. Instead an artificial dielectric is produced by supporting small metal disks or spheres in a lattice arrangement to simulate the molecules of a true dielectric. This lens is quite broadband.

ANTENNA, LENS (DELAY OF). See **antenna, lens (artificial dielectric of).**

ANTENNA, LENS (METALLIC). Parallel metal surfaces placed parallel to the **E field** produced by a radiator. Since the **phase velocity** in **waveguide** is larger than the free-space velocity, the net phase change at a given point may be controlled by varying the length of the path the wave travels between the surfaces. Thus a spherical wave may pass through the lens and emerge a plane wave because of the selective phase-shift functions performed. (See **antenna, lens.**)

ANTENNA, LENS (PATH LENGTH). This lens retains the hyperbolic shape of the artificial dielectric lens, but contains parallel conducting sheets which are perpendicular to the E field. The sheets may be corrugated or set at an angle to produce a longer path length through the lens than through free space, so that an equivalent **angle of refraction** is produced.

ANTENNA, LONG-WIRE. A linear antenna (see **antenna, linear**) which, by virtue of its considerable length in comparison with the operating wavelength, provides a directional **radiation pattern.**

ANTENNA, LOOP. An **antenna** consisting of one or more complete turns of conductor and functioning by virtue of the circulatory current therein.

ANTENNA, LOOPSTICK. A reduced-size loop antenna (see **antenna, loop**) having the loop wound on a rod or bar of some type of **ferrite** material.

ANTENNA, MARCONI-FRANKLIN. This array (see **antenna array**), one of the first employed for high-speed shortwave point-to-point communication, consists of a front curtain of vertical radiators, each consisting of several cophased dipoles in series, and another curtain of reflecting wires of the same construction situated one-quarter wavelength to the rear. These are twice as many reflectors as radiators.

ANTENNA, MARCONI OR GROUNDED. An **antenna** with one end of its radiating surface grounded. It may be considered as a transmission line open-circuited at the far end and driven at the sending end, which is the junction between antenna and ground.

ANTENNA, MARKER. The transmitting antenna for a **marker beacon.**

ANTENNA, MULTIPLE-TUNED. A low-frequency **antenna** having a horizontal section with a multiplicity of tuned vertical sections

ANTENNA, MUSA. A "multiple-unit steerable antenna" consisting of a number of stationary antennas, the composite major lobe (see **lobe, major**) of which is electrically steerable.

ANTENNA OHMIC RESISTANCE. See **antenna resistance.**

ANTENNA, OMNIDIRECTIONAL. An antenna producing essentially constant **field strength** in azimuth, and a directive **radiation pattern** in elevation.

ANTENNA, OSCILLATING DOUBLET. A reference standard against which the directional characteristics of an antenna may be compared. Ideally it consists of two closely spaced charges of opposite sign, both oscillating in the same phase. Also, it may be regarded as an infinitely-short, linear current-element.

ANTENNA, PARABOLIC. A directional antenna (see **antenna, directional**) using some form of a paraboloidal mirror either to convert plane waves into spherical waves or to convert spherical waves into plane waves. The **reflector** is fed or "illuminated" by the use of dipoles, waveguide feed systems, or horns. The simple parabolic mirror is truly a broad-band device.

ANTENNA, PARASITIC. An antenna element that operates as a part of an **array** without direct connection to the source of power (or in the case of a receiver, without connection to the receiver terminals).

ANTENNA PATTERN. See **radiation pattern.**

ANTENNA, PENCIL-BEAM. A unidirectional antenna (see **antenna, unidirectional**), so designed that cross sections of the **major lobe** by planes perpendicular to the direction of maximum radiation are approximately circular.

ANTENNA, PILL-BOX. A cylindrical, **parabolic reflector** enclosed by two plates perpendicular to the cylinder, so spaced as to permit the propagation of only one **mode** in the desired **direction of polarization.** It is fed on the focal line.

ANTENNA, POCKET. A non-protruding slot antenna (see **antenna, slot**) developed for aircraft applications.

ANTENNA POLYROD. A form of dielectric antenna (see **antenna, dielectric**) made of polystyrene rods.

ANTENNA POWER GAIN. In a given direction 4π times the ratio of the **radiation intensity** in that direction to the total power delivered to the antenna.

ANTENNA, QUARTER-WAVE. An **antenna** which is electrically one-quarter of a wavelength long. It may be physically longer or shorter than one-quarter wavelength in free space.

ANTENNA RADIATION PATTERN. See **radiation pattern.**

ANTENNA RADIATION RESISTANCE. See **radiation resistance.**

ANTENNA, RECEIVING. An **antenna** used for the reception of radiated electromagnetic waves.

ANTENNA RESISTANCE. The quotient of the power supplied to the entire **antenna circuit** by the square of the effective antenna current referred to a specified point. Antenna resistance is made up of such components as **radiation resistance,** ground resistance, radio-frequency resistance of conductors in the antenna circuit, and equivalent resistance due to corona, eddy currents, insulator leakage, and dielectric power loss.

ANTENNA RESONANT FREQUENCY. That frequency or frequencies at which the **antenna** appears as a pure resistance.

ANTENNA, RHOMBIC. An **antenna** composed of long-wire radiators comprising the sides of a rhombus. The antenna usually is terminated in an impedance. The sides of the rhombus, the angle between the sides, the elevation, and the termination are proportioned to give the desired **directivity.**

ANTENNA, ROTARY. Any form of **antenna** which may be rotated around its center in order that its directional characteristics may be used to advantage.

ANTENNA, SCANNING. A directional antenna (see **antenna, directional**) employed in **radar** which mechanically or electrically causes its radiation to scan periodically a given arc or solid angle.

ANTENNA, SECTIONALIZED VERTICAL. A vertical antenna (see **antenna, vertical**) which is insulated at one or more points along its length. The insertion of suitable reactances or applications of a driving voltage across the insulated points results in a modified current distribution giving a more desired **radiation pattern** in the vertical plane.

ANTENNA, SECTORAL. See **horn, sectoral.**

ANTENNA, SERIES-FED VERTICAL. A vertical antenna (see **antenna, vertical**) which is insulated from ground and energized at the base.

ANTENNA SERIES LOADING. A method of tuning whereby the effective height of a vertical colinear array may increase with proper nonradiating impedances employed between the elements. (See **antenna, colinear.**)

ANTENNA, SHAPED-BEAM (PHASE-SHAPED). A unidirectional **antenna** (see **antenna, unidirectional**) whose major lobe differs materially from that obtainable from an aperture of uniform phase. A $\csc^2 \theta$ beam is a shaped beam whose intensity in some plane varies as $\csc^2 \theta$ over a prescribed range, where θ is a polar angle in that plane. The half-power width in planes, perpendicular to this plane, is approximately constant for the prescribed range of θ.

ANTENNA, SHUNT-FED VERTICAL. A vertical antenna (see **antenna, vertical**) connected to ground at the base and energized at a point suitably positioned above the grounding point.

ANTENNA, SIMPLE DOUBLET. See **antenna, doublet; antenna, dipole.**

ANTENNA, SLEEVE-DIPOLE. A dipole antenna (see **antenna, dipole**) surrounded in its central portion by a coaxial sleeve.

ANTENNA, SLEEVE STUB. An antenna consisting of half of a sleeve-dipole antenna projecting from an extended metal surface.

ANTENNA, SLOT. A radiating element formed by a slot in a metal surface.

ANTENNA, SPACED. An **antenna array** used for **diversity reception,** consisting of several antennas spaced several wavelengths apart.

ANTENNA, SPHERICAL. A theoretical radiator, spherical in shape.

ANTENNA, SPIDER-WEB. An **antenna array** consisting of several, different length doublets coupled to a common transmission line for wide band (standard broadcast and shortwave) reception. Suitable frequency-sensitive elements are used, so that essentially only one antenna functions at a given frequency. The name is derived from its physical appearance.

ANTENNA, SQUARE LOOP. An array (see **antenna array**) consisting of four dipole radiators arranged in a square. The dipoles may take the form of folded or simple dipoles fed at the center.

ANTENNA, STEERABLE. A directional antenna (see **antenna, directional**) whose major lobe (see **lobe, major**) can be readily shifted in direction.

ANTENNA, STERBA CURTAIN. An array employing a front curtain of several radiators spaced one-half wavelength, with uniphased currents, and a similar reflector curtain directly excited by transmission lines. Radiation is directed perpendicularly to the line of the array.

ANTENNA, "SUPER-TURNSTILE." An improved version of the turnstile antenna. It has a broader bandwidth and is easier fed than the original turnstile developed by Brown. (See **antenna, turnstile.**)

ANTENNA, TOP-LOADED VERTICAL. A vertical antenna (see **antenna, vertical**) so constructed that, because of its greater size at the top, there results a modified current distribution giving a more desirable **radiation pattern** in the vertical plane. A series reactor may be connected between the enlarged portion of the antenna and the remaining structure.

ANTENNA, TRIDIPOLE. An omnidirectional, horizontally-polarized antenna consisting of three dipoles displaced from each other by 60° in the horizontal plane. The radiators are curved, causing the array to have a circular appearance.

ANTENNA, TURNSTILE. An antenna composed of two dipole antennas (see **antenna, dipole**), normal to each other, with their axes intersecting at their midpoints. Usually, the currents are equal and in **phase quadrature.**

ANTENNA TURNSTILE (BROWN). A type of antenna developed by Brown. (See **antenna, turnstile.**)

ANTENNA TURNSTILE, DE MARS. An improved turnstile antenna in which certain phasing operations are performed at the base of the supporting tower rather than at the antenna elements. (See **antenna, turnstile.**)

ANTENNA, UNIDIRECTIONAL. An **antenna** which has a single well-defined direction of maximum **gain.**

ANTENNA, UNIDIRECTIONAL COUPLET. A two-dimensional array made up of pairs of isotropic antennas spaced a quarter wave apart and phased by a quarter period. The directional pattern of each pair is a cardioid. This is thus a type of broadside array. (See **antenna, broadside array.**)

ANTENNA, V. A V-shaped arrangement of conductors, balanced-fed at the apex, and with included angle, length, and elevation proportioned to give the desired **directivity.**

ANTENNA, WAVE (BEVERAGE ANTENNA). A directional antenna (see **antenna, directional**) composed of a system of

parallel, horizontal conductors from one-half to several wavelengths long, and terminated to ground at the far end in its characteristic impedance.

ANTENNA, YAGI. An array with one or more parasitic elements (see **antenna, parasitic**) in addition to the driven element or elements. The parasitic element "captures" energy from the field produced by the driven antenna and reradiates it in a phase (relative to the phase of the radiation from the driven unit) that is a function of both the spacing of the elements and the length of the parasitic element. If the resultant radiation pattern has its maximum in the direction of the driven element, the parasitic element is called a reflector, whereas if the maximum radiation is in the direction of the parasitic antenna, it is called a director.

ANTI-. A prefix used before the name of an elementary particle to indicate another particle with certain symmetry characteristics. (See **antineutrino; antiproton; antiparticle;** etc.)

ANTIBONDING ORBITAL. A **molecular orbital** whose energy increases as the two atoms are brought closer together, so that it corresponds to a net repulsion—in contradistinction to a **bonding orbital** which has a minimum energy near the appropriate interatomic distance, and gives rise to a **valence bond.**

ANTICAPACITANCE SWITCH. A switch designed to present the smallest practical series **capacitance** when in its open position

ANTICATHODE. In an **x-ray tube,** the target on which the electron beam is focused and from which the x-rays are radiated.

ANTICOINCIDENCE. See **coincidence, anti-.**

ANTICOINCIDENCE CIRCUIT. A circuit with two input terminals which delivers an output pulse if one input terminal receives a pulse, but delivers no output pulse if pulses are received by both input terminals simultaneously or within an assignable time interval. (See **resolving time; coincidence.**)

ANTICOINCIDENCE COUNTER. An arrangement of **counters** and associated circuits which will record a count if and only if an ionizing particle passes through certain of the counters but not through the others.

ANTICOMMUTATOR OF TWO OPERATORS. If A, B are two operators their anticommutator is $\{A, B\}_+ = AB + BA$.

ANTICYCLONE. A large atmospheric eddy, whose horizontal dimensions vary from a few hundred miles to several thousand miles. It rotates in a clockwise manner in the northern hemisphere and a counterclockwise manner in the southern hemisphere when viewed from above. The barometric pressure within an anticyclone is high relative to its surroundings, and a pressure gradient exists from its center toward its periphery. A well-developed anticyclone is essentially an **air mass.**

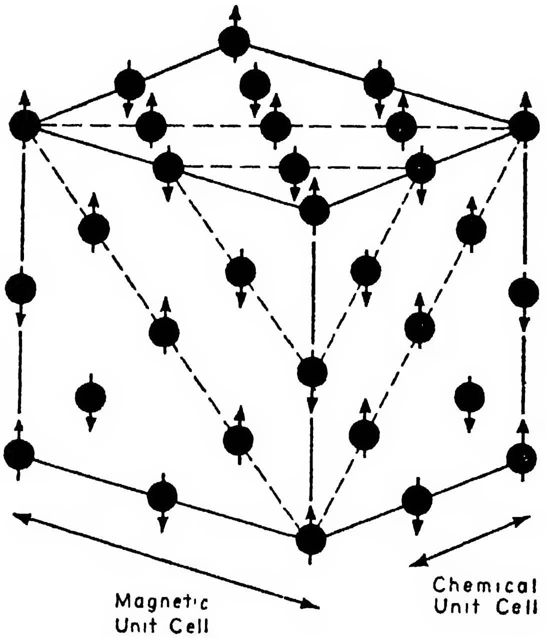
ANTICYCLOGENESIS. The process which creates or develops a new **anticyclone.** The word is applied also to the process which produces an intensification of a pre-existing anticyclone

ANTICYCLOTRON. A form of **traveling-wave tube.**

ANTIFERROMAGNETIC EXCHANGE INTEGRAL. In the **Heisenberg theory of ferromagnetism,** the interaction between the spins of electrons on neighboring atoms depends on the sign of the **exchange integral.** Under certain circumstances, this integral may have a sign which favors an antiparallel arrangement of the spins. This is interpreted as leading to the phenomena of **antiferromagnetism.**

ANTIFERROMAGNETISM. The observed **susceptibility curves** of certain substances suggest that the system has gone into a state analogous to the ferromagnetic state, but with neighboring spins antiparallel, instead of parallel. That is, such substances exhibit a paramagnetism (low positive susceptibility) that varies with temperature in a manner similar to **ferromagnetism,** exhibiting a **Curie point.** Their resulting **superlattices** have been observed by **neutron diffraction.** The interaction giving preference to the antiparallel arrangement is believed to be an **exchange force,** similar to that invoked in the **Heisenberg theory of ferromagnetism,** but opposite in sign. Evidence from face-centered crystals

has suggested the importance of super-exchange between next-nearest neighbors, through the anions.



Antiferromagnetic state spin structure of manganese oxide as determined by Shull, Strauser and Wollan

ANTIHALATION BACKING. In the recording of spectra by the photographic method, there is a tendency for lines to be broadened by light passing through the photographic plate and then being reflected back to the emulsion. This broadening of lines is called halation. It may be largely overcome by coating the back of the plate with a non-reflecting coating. Some spectrographic plates now have a colored layer between the emulsion and the glass for the purpose of absorbing this undesired light.

ANTIHUNT TRANSFORMER. A transformer used in d-c **feedback systems** as a stabilizing network. In general practice the primary of this transformer is in series with the load connected to the system. The secondary of the transformer has a voltage which is proportional to the derivative of the primary current, and is thus an appropriate signal to be fed back into some other part of the **loop** to prevent **self-oscillations.**

ANTIHUNTING CIRCUIT. A **stabilizing** or **equalizing circuit** used in a closed-loop feedback system to modify the response of the system in order that **self-oscillations** may be prevented.

ANTIMONY. Metallic element. Symbol Sb Atomic number 51.

ANTIMONY ELECTRODE. See **electrode, antimony.**

ANTINEUTRINO. (1) In the most frequent usage, a particle whose emission is postulated to accompany radioactive decay by **positron** emission or electron **capture.** The antineutrino may be looked upon as a hole in the negative-energy Dirac sea of neutrinos. Since there is no possibility of charge differentiation between the antineutrino and the **neutrino,** differentiation between these two particles can be made only on the basis of such properties as the sign of the ratio of magnetic moment to angular momentum. Neither the neutrino nor the antineutrino has been detected.

(2) In a less common usage the terms neutrino and antineutrino are used in reverse sense to that stated above, i e, the neutrino is said to accompany positron emission and the antineutrino, electron emission.

ANTINODES (LOOPS). The points, lines, or surfaces in a standing wave (see **wave, standing**) system where some characteristic of the wave field has maximum amplitude The appropriate modifier should be used with the word "antinode" to signify the type that is intended (pressure antinode, velocity antinode, etc). (See also **loop.**)

ANTINOISE MICROPHONE. See **microphone, antinoise.**

ANTIPARALLEL. Having opposite senses, as two vectors which are parallel, but which are placed head to tail.

ANTIPARTICLE. One interpretation of the **Dirac electron theory** as applied to any **fermion** is that there exists a negative energy sea of such fermions. A hole in this distribution of negative energy particles is the corresponding antiparticle. The antiparticle has a charge equal and opposite to that of the corresponding particle and its magnetic moment is oppositely directed with respect to its spin, compared with their mutual orientation in the particle. A particle and its antiparticle appear simultaneously in **pair production,** or disappear simultaneously in the production of **annihilation radiation.** (See **positron theory; Majorana particle; antiproton.**)

ANTI-PLUGGING RELAY. A **relay** used in some control systems to prevent **plugging.**

ANTIPROTON. An elementary particle having a mass essentially equal to that of the proton, differing from the proton in the sign of its charge, which is negative. Its detection was announced by the University of California and the U.S. Atomic Energy Commission. Protons which had been accelerated to an energy of 6,200 mev in the **bevatron,** the proton synchrotron of the University of California Radiation Laboratory at Berkeley, were allowed to collide with a copper target. Negatively-charged particles coming out in a forward direction from this collision were selected and separated in momentum by a focusing and analyzing magnet system to provide a beam of negative particles of known momentum. After a time of flight of about one-tenth of a microsecond, this beam may be expected to consist mainly of negative pi- and mu-mesons, with some negative K-mesons (mass about 965 electron masses) and possibly negative protons. These particles were then distinguished both by measurement of their time of flight from the target (since particles of different mass have different velocities for given momentum) and by means of a device measuring the velocity of each particle passing through by the angle of its **Cerenkov radiation.** In this way the presence of negative particles with protonic mass (within about ten per cent) and distinct from the known K-particles and **hyperons** was established. Their rate of production for the momentum and direction of this experiment was about one negative proton for every 50,000 negative pi-mesons with the same momentum and direction. (Cf. **anti-** and **antiparticle.**)

ANTIREGENERATIVE DEVICES. See **neutralization; equalizer.**

ANTIRESONANCE (PARALLEL IMPEDANCE). In general, a condition of maximum impedance, as results when two or more impedors are connected in parallel, under such conditions that (for resistanceless impedors), Z approaches infinity when $\omega_1{}^2 = 1/LC$. The term antiresonance is commonly used with suitable modifiers. (See **antiresonance, displacement** and **antiresonance, velocity.**)

ANTIRESONANCE, DISPLACEMENT. Displacement antiresonance exists between a body, or system, and an applied sinusoidal force if any small change in the frequency of the applied force causes an increase in the amplitude of displacement at the **driving point.**

ANTIRESONANCE, VELOCITY. Velocity antiresonance exists between a body, or system, and an applied sinusoidal force if any small change in the frequency of the applied force causes an increase in velocity at the **driving point,** or if the frequency of an applied force is such that the absolute value of the driving-point impedance (see **impedance, driving point**) is a maximum.

ANTIRESONANT FREQUENCY. That frequency at which the impedance of a given system (electrical, acoustical, dynamical) is very high in contradistinction to its **resonant frequency** at which its impedance is very low. The commonly-used unit is the cycle per second In cases where there is a possibility of confusion it is necessary to specify the type of antiresonant frequency, e.g., displacement antiresonant frequency or velocity antiresonant frequency. (See **antiresonance, displacement,** and **antiresonance, velocity.**)

ANTI-SIDE-TONE. In the older types of telephone subscribers' sub-set the sound going into the **transmitter** (mouthpiece) can be heard in the receiver. This is known as sidetone and has some objectionable features. It causes the speaker unconsciously to lower the voice and thus reduces the energy transmitted, and it also increases the effect of any local noise by causing it to appear in the receiver. It is thus desirable to eliminate or at least reduce the side-tone and special circuits and equipment have been devised. These sub-sets are known as anti-side-tone sets.

ANTISTOKES LINES. When all the molecules are in the normal state, the only possible transitions caused by exciting radiation are those in which the scattered or fluorescent light is of the same or lower frequency than the incident light (**Stokes Lines**). However if some of the atoms or molecules are in states other than normal. lines of frequencies higher than that of the incident light (Antistokes Lines) may result. (See **Raman effect.**)

ANTISYMMETRIC. (1) A function which is transformed into its negative when the variables of the function are interchanged in pairs. (2) The term is also applied to any physical

system in which each point has properties opposite to those of a point symmetrically located with respect to it, e.g., an electric **dipole** is antisymmetric in its charge distribution. (See **symmetric.**)

ANTITRADE WINDS. Above the northeast and southeast **trade winds** there frequently is present westerly winds known as the antitrades. Reversal of direction occurs as low as a few thousand feet or as high as 3–4 miles.

ANTI-TRANSMIT-RECEIVE SWITCH. See **transmit-receive switch, duplexer.**

ANTONOFF RULE. The tension at the interface between two saturated liquid layers which are in **equilibrium** is equal to the difference between the individual **surface tensions** against air or vapor of the two saturated solutions. This rule is approximate only and a number of exceptions are known.

ANVIL. The characteristic fibrous, spreading top of a **cumulonimbus** cloud in full development.

APERTOMETER. A device designed by Abbe for measuring the numerical aperture (see **aperture, numerical**) of **microscope objectives.**

APERTURE. Qualitatively, any opening through which radiation or particle fluxes may pass. In optical and electron-optical instruments, the term aperture has acquired specific or quantitative meanings given below.

APERTURE ANGLE. The angle subtended by the radius of the **entrance pupil** of an optical instrument at an axial **object point.**

APERTURE COMPENSATION. The reduction of **aperture distortion** by boosting the high frequency gain of the television camera video amplifier.

APERTURE DISTORTION. Distortion of a television signal due to the size of the electron **scanning beam.** The result is a loss of detail or resolution.

APERTURE ILLUMINATION. The field distribution in amplitude and phase over the aperture.

APERTURE LENS. See **lenses, apertures as electric.**

APERTURE MASK. A perforated plate placed in a color-television tube between the **focusing** and **accelerating electrodes,** and the tri-color phosphor screen.

APERTURE, NUMERICAL. Abbe named the quantity n sin u the numerical aperture (N.A.) of a lens. u is the angular radius of the lens as seen from a point on the **optical axis** at the object, and n is the **index of refraction** of the medium between the object and the lens.

APERTURE OF A LENS. The diameter of the lens. (See **aperture, relative,** and **aperture, numerical.**)

APERTURE OF A UNIDIRECTIONAL ANTENNA. That portion of a plane surface near the **antenna,** perpendicular to the direction of maximum radiation, through which the major part of the radiation passes.

APERTURE, RELATIVE (OR F-NUMBER). The ratio of the **focal length** of an **optical system** to the diameter of the **entrance pupil.**

APERTURE STOP. That opening in an **optical system,** frequently one of the lenses itself, which limits the size of the bundle of rays which can pass from a point on the object to the corresponding point of the image The aperture stop of a system may be a different opening for objects at different distances from the system.

APERTURE, TELEVISION. In transmitting the **television** image it is necessary to break it down into elements of very small area. In early mechanical scanning methods this was done by "observing" the image through an opening or aperture which scanned the scene. In modern equipment the scanning is no longer done mechanically but the term aperture is used to denote the size of one of the elements into which the picture is broken for transmission.

APEX. The tip, point, or summit of a curve or surface. (See **vertex.**)

APLANAT, TRIPLE. A **compound lens** made of two **negative lenses** of flint glass, between which is cemented a double-convex lens of crown glass.

APLANATIC LENS SYSTEM. A system which satisfies the equation, $ny \sin u = n'y' \sin u' =$ constant. Unprimed letters refer to

object space, primed to **image space.** n, n' are indices of refraction, y, y' are distances of a **point object** and its **point image** from the **optical axis;** and u, u' are angles made by a ray with the optical axis. This equation is known as Abbe's sine condition.

APLANATIC POINTS. Two points on the axis of an **optical system** which have the property that rays proceeding from one of them shall all converge to, or appear to diverge from, the other. The two foci of an ellipsoid of revolution are aplanatic points.

APLANATIC SURFACE. An optical surface for which two **aplanatic points** exist.

APOCHROMATIC SYSTEM. A system which is **aplanatic** and **achromatic** for two or more colors, and is free from secondary spectrum.

APOSTILB. A unit of **luminance,** equal to 1/10,000 **lambert.**

APPARENT CANDLE POWER. A measure of the equivalent **luminous intensity** of an **extended source** at a specified distance in terms of a **point source** which would produce the same **illumination** at the same distance.

APPARENT MOLAR QUANTITY. For a solution containing n_1 moles of solvent and n_2 moles of solute, an apparent molar quantity is defined as

$$\frac{X - n_1 x_1}{n_2}$$

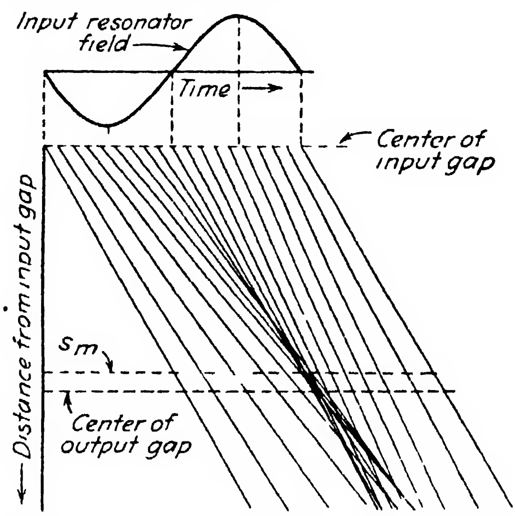
where X is the value of the quantity for the whole solution and x_1 the molar quantity for the pure solvent, e.g., the apparent molar volume of the solute is

$$\frac{V - n_1 v_1}{n_2}$$

V being the total volume and v_1 the volume per mole of the solvent.

APPEARANCE POTENTIAL (MASS SPECTROMETER). The minimum energy that the electron beam in the ion source must have in order to produce ions of a particular species when a molecule is ionized.

APPLEGATE DIAGRAM. A graphical explanation of the process of bunching in **velocity-modulation** tubes. The example below is for the two-cavity **klystron.** In this diagram the positions of electrons that pass through the output gap at various instants in the cycle of buncher voltage is shown as a function of time. The slope of any curve is equal to the velocity with which the corresponding electron leaves the input gap.



Applegate diagram (By permission from 'Microwave Theory and Techniques' by Reich et al. Copyright 1953 D. Van Nostrand Co. Inc.)

Close spacing of the velocity lines indicates that many electrons pass a given point in a short time interval, that is, that the electrons pass in bunches.

APPLETON LAYER. The ionospheric $\mathbf{F_1}$ and $\mathbf{F_2}$ **layers.**

APPLICATOR (APPLICATOR ELECTRODES). In dielectric heating usage, appropriately-shaped conducting surfaces between which is established an alternating electric field for the purpose of producing **dielectric heating.**

APPLIED SHOCK. Any excitation which, if applied to a system would produce **shock motion** within the system.

APPROXIMATION, CLASSICAL. See **Wentzel-Kramer-Brillouin approximation.**

APPROXIMATE IN THE MEAN. A function $f(x)$ is approximated in the mean by the sum

$$\sum_{i=1}^{n} a_i u_i \quad \text{if} \quad \lim_{n\to\infty} \int (f - \Sigma a_i u_i)^2 w dx = 0$$

where w is the appropriate **weighting function.**

AQUADAG COATING. A coating of a trade-named preparation of graphite applied to the insides of some tubes (particularly cathode-ray) to serve (1) as a sink for secondary electrons, (2) as a post-deflection **acceleration anode.**

ARAGO SPOT. A bright point which, owing to **diffraction,** appears at the center of the shadow of a circular object in light from a **point source.**

ARC. A low-voltage, high-current electrical discharge, as contrasted with a spark.

ARC BACK (BACKFIRE). This is the occurrence of an arc from **anode** to **cathode** in a gaseous rectifier **tube.** Normally such a tube has **electrons** flowing from the cathode to the anode but under certain conditions excessive heating of the anode, excessive voltage across the tube, or other effects may cause the anode to emit electrons and allow an arc discharge to take place in a direction opposite to the normal direction. Under many circuit conditions this may destroy the tube or it may merely open the protective devices.

ARC BAFFLE. An obstruction placed in mercury-pool tubes to prevent mercury from splashing onto the anode. Also called splash baffle. Arc baffles are illustrated in the figures accompanying the definitions of **excitron** and **ignitron.**

ARC CHUTE. A restricted passage around a set of contacts. When the contacts open the resulting arc is forced into the chute by chimney action. The arc-path is lengthened and deionization is accomplished in less time.

ARC CONVERTER. A form of **oscillator** utilizing an electric arc as the generator of alternating or pulsating current.

ARC DISCHARGE. The electric arc, so called because of the shape of the "flame," was discovered by Davy about 1808. It is a type of discharge between electrodes in a gas or vapor which is characterized by a relatively low voltage drop and a high current density. The two types which are of considerable practical importance are the arc in open air and the arc in gases at low pressure. The familiar carbon-arc (see **arc lamp**) and the electric-arc furnace are examples of the former. The **mercury-arc tube** is the most important example of an arc in a gas at low pressure. Here the gas is the mercury vapor, the **cathode** is the mercury pool, and the **anode** is usually carbon. The discharge in **thyratrons** and other gas-filled hot cathode tubes is often called an artificial arc discharge since it is characterized by low voltage and high current density. It is not a true arc, however, since the cathode heat energy is supplied by an external source and not by the discharge itself.

ARC, KEEP-ALIVE. In mercury-pool tubes, a current between the cathode and an auxiliary or excitation anode. Sufficient current is drawn by this anode to maintain a cathode spot until such time as conduction to the main anode is desired. (See **ignitron; excitron.**)

ARC LAMP. The electric-arc lamp has, as its

source of illumination, an electric **arc** struck between two electrodes. In contrast to the incandescent lamp, in which the illumination results from a heated filament, and vapor lamps, in which the illumination is derived from a vapor made luminous by electric current, the light from an arc lamp comes from the highly incandescent crater of the positive electrode, and from the heated, luminous, ionized gases surrounding the arc.

ARC, MERCURY. An electric arc that passes through mercury vapor.

ARC-THROUGH. Anode conduction in a gas tube in the normal or forward direction, but at a time when it should not be conducting.

ARCHIMEDES PRINCIPLE. A body immersed in a fluid is acted on by a **buoyancy** force, made evident by a loss of weight, equal to the weight of displaced fluid.

ARCTIC SMOKE. A form of fog caused by rapid evaporation from the surface of warmer water when very cold, dry air streams across it.

AREA. (1) If a parallelogram has sides denoted by the vectors **A** and **B**, its area is given by the vector product, $\mathbf{C} = \mathbf{A} \times \mathbf{B}$, which is perpendicular to the plane determined by **A** and **B**. The scalar magnitude of **C** equals that of the area and the direction of **C** is

arbitrarily taken as the direction of the outward normal to the surface. (2) In **calculus,** the area of a surface may be found by integration. If $y = f(x)$ describes a curve, the area bounded by the curve, the X-axis, and the ordinates $(a\ b)$ is

$$\int_a^b f(x)dx.$$

A double integral may also be used, for an infinitesimal **surface element** in the XOY-plane is $dxdy$ and the area over a region S is

$$\iint_S dxdy.$$

For a curved surface described by $z = f(x,y)$ the area is

$$\iint_S f(x,y)dxdy.$$

(See also **integral, surface.**)

AREAL DENSITY. **Surface density.**

AREOMETRIC METHOD. The method of determining the **specific gravity** of a liquid by measuring the loss of weight of a solid of known mass suspended in the liquid If the volume of the solid can be determined by measurement, the density of the liquid may be determined

ARGAND DIAGRAM. A graphical method of representing a function of a **complex variable,** $z = x + iy$ There are two perpendicular axes, the real part of the function being plotted on the real axis, usually the horizontal one, and the imaginary part on the imaginary or vertical axis Points plotted on the diagram for various values of the number pair (x,y) can then be joined to give a curve for the function in the complex plane.

ARGON. Gaseous element Symbol A Atomic number 18.

ARGUMENT. (1) The independent variable x for a function $f(x)$ and also the values of the independent variable in a numerical table, such as the angles in a table of trigonometric functions or the numbers in a table of logarithms. (2) See **amplitude.**

ARITHMETIC PROGRESSION. A sequence of the form a, $a + d$, $a + 2d$, $a + 3d$, $\cdots$ where a is the first term and d is the constant difference between any two successive terms. For its sum see **series, arithmetic.**

ARM. See **branch.**

ARMATURE. (1) One of the essential parts of the dynamo electric machine. In a **generator,** the armature is the winding in which **electromotive force** is induced In the **motor** armature, conductors carry the input current which, in the presence of a **magnetic field,** produces a **torque** and effects the transformation of electrical into mechanical energy. In d-c machines it is the rotor, but the a-c armature may be rotor or stator Larger size synchronous machines always have stationary armatures The reluctance of the magnetic circuit to the flux which must link the conductors of the armature in order to generate electric energy, is decreased by providing a core of soft iron or steel, on the surface of which the conductors are embedded in slots suitably provided in the core. The armature windings of a d-c generator are terminated at the segments of a **commutator,** by means of which the alternating e m f.'s induced in the armature are rectified and transferred by **brushes** from the moving rotor to stationary terminals The conductors must be separately insulated, as must be also the commutator segments, and must be well braced and anchored in their slots to resist the electromagnetic and mechanical forces which tend to displace them (2) The moving element of a magnetically actuated **relay.**

ARMATURE REACTION. This term refers to the reaction of the magnetic field produced by the current flowing in the armature conductors upon the main magnetic field of a dynamo machine. The result is a distortion of the magnetic field, the extent depending upon the reluctance of the magnetic circuit, the arrangement of the armature windings, the type field structure, and the phase angle between the armature voltage and current In d-c machines the effect is to increase the flux at some pole tips and decrease it at others, while in a-c machines the effect depends upon the field structure and the phase angle of the armature current and voltage The flux may be distorted as in the d-c machine, it may be changed in magnitude but undistorted in wave form or it may be changed in magnitude and shifted in position with respect to the field windings. Armature reaction is an important

factor in the speed and voltage regulation of the machines.

ARMSTRONG OSCILLATOR. A tuned-plate, tuned-grid **oscillator** due to E. H. Armstrong.

ARRANGEMENT. See **permutation.**

ARRAY. (1) A collection of numbers or functions ordered into some sort of table (see **determinant** and **matrix**). (2) See **antenna, array.**

ARRAY, CURVED. See **source, curved line,** and **source, curved surface.**

ARRAY, LINEAR. See **source, straight line.**

ARREST POINT. A temperature at which a **system** of more than one **component** that is undergoing heating or cooling absorbs or yields heat without change in temperature, thus interrupting the heating or cooling process.

ARRESTER. A protective device used to bypass to ground destructive lightning discharges.

ARITHMETIC ELEMENT. That part of a **computer** which performs arithmetic operations.

ARRHENIUS-GUZMAN EQUATION. A relation between the viscosity η, and temperature T, at constant pressure,

$$\eta = A \exp \frac{B}{RT}$$

where A, B are constants. B may be identified with the **activation energy for liquid flow.**

ARRHENIUS THEORY OF ELECTROLYTIC DISSOCIATION. The theory proposed by Arrhenius, which states that when an electrolyte (an acid, base, or salt) is dissolved in water, a substantial portion of its molecules dissociate spontaneously into positive and negative ions, which, upon the application of an electrical potential difference to the solution, are attracted to the electrode of opposite sign and discharge, thus conducting current through the solution. This dissociation increases the number of particles in the solution, and thus changes the osmotic pressure, elevation of the boiling point, and depression of the freezing point to an extent determined by the degree of dissociation and concentration of the electrolyte. The degree of dissociation increases with dilution, becoming complete at "infinite dilution." Modern discoveries and interpretations have modified considerably this view of electrolytic dissociation. (See **theory of electrolytes** for statement of current views.)

ARRHENIUS VISCOSITY FORMULAE. (1) Effect of temperature on viscosity of a liquid

$$d \ln (\eta v^{1/3})/dT = k_1/T^2,$$

where v is the specific volume, k_1 is the constant

(2) Viscosity of electrolyte and non-electrolyte solutions

$$\eta = A^x$$

where x is the concentration, A is the constant.

(3) Viscosity of a sol

$$\log \frac{\eta}{\eta_\infty} = kC$$

where η_∞ is the viscosity of the medium, C is the molecular concentration of the sol-forming material.

ARRL. Abbreviation for American Radio Relay League.

ARSENIC. Element. Symbol As. Atomic number 33.

ARTICULATION (PERCENT ARTICULATION) AND INTELLIGIBILITY (PERCENT INTELLIGIBILITY). Of a communication system, the percentage of the speech units spoken by a talker or talkers that is understood correctly by a listener or listeners. The word "articulation" is customarily used when the contextual relations among the units of the speech material are thought to play an unimportant role; the word "intelligibility" is customarily used when the context is thought to play an important role in determining the listener's perception. It is important to specify the type of speech material and the units into which it is analyzed for the purpose of computing the percentage. The units may be fundamental speech sounds, syllables, words, sentences, etc. The percent articulation or percent intelligibility is a property of the entire communication system: talker, transmission equipment or medium, and

listener. Even when attention is focused upon one component of the system (e.g., a talker, a radio receiver), the other components of the system should be specified.

ARTICULATION, CONSONANT (PERCENT CONSONANT ARTICULATION). The percent **articulation** obtained when the speech units considered are consonants (usually combined with a vowel into meaningless syllables).

ARTICULATION, SOUND (PERCENT SOUND ARTICULATION). The percent **articulation** obtained when the speech units considered are fundamental sounds (usually combined into meaningless syllables)

ARTICULATION, SYLLABLE (PERCENT SYLLABLE ARTICULATION). The percent **articulation** obtained when the speech units considered are syllables (usually meaningless and usually of the consonant-vowel-consonant type).

ARTICULATION, VOWEL (PERCENT VOWEL ARTICULATION). The percent **articulation** obtained when the speech units considered are vowels (usually combined with consonants into meaningless syllables).

ARTIFICIAL ANTENNA. A dummy antenna. (See **antenna, dummy.**)

ARTIFICIAL EAR. A device for the measurement of earphones which presents an acoustic impedance (see **impedance, acoustic**) to the earphone equivalent to the impedance presented by the average human ear. It is equipped with a microphone for measurement of the sound pressures developed by the earphone.

ARTIFICIAL LARYNX. A reed actuated by the air from an opening in front of the throat, through which breathing takes place. The device assists the speech of a person on whom a tracheotomy has been performed

ARTIFICIAL LINE. A **network** which simulates the electrical characteristic of a **transmission line.**

ARTIFICIAL LOAD. A dissipative but essentially nonradiating device having the impedance characteristics of an **antenna, transmission line,** or other practical utilization circuit.

ARTIFICIAL RADIOACTIVITY. (1) **Induced radioactivity.** (2) Radioactivity induced under controlled conditions.

ARTIFICIAL VOICE. A small **loudspeaker** mounted in a shaped baffle which is proportioned to simulate the acoustical constants of the human head. The artificial voice is used for calibrating and testing close-talking microphones. (See **microphone, close-talking.**)

ASA. Abbreviation for American Standards Association.

ASPECT RATIO. In television, the ratio of the frame width to the frame height.

ASPHERIC SURFACE. A surface of a lens or mirror which has been changed slightly from a spherical surface as an aid in reducing **aberrations.** **Parabolic mirrors** for telescopes and **Schmidt corrector plates** are common aspheric surfaces.

ASSEMBLY. A collection of systems each consisting of the same number of particles (i.e., molecules, atoms, etc.), each system in a container of the same shape, each system having the same total energy, but without any other restriction on the coordinates and momenta

ASSEMBLY, COOPERATIVE. An assembly in statistical mechanics in which the interactions between the systems composing the assembly are not negligible. The state of a given system is largely determined by the states of the neighboring systems.

ASSEMBLY, IDEAL. An assembly in statistical mechanics in which the interactions between the systems composing the assembly can be neglected, such as a perfect gas or an ideal solution

ASSEMBLY, MICROCANONICAL. An assembly in statistical mechanics in which the variation in energy (or other independent variable) of all the systems lies within an infinitesimal range Over this range, the assembly is in statistical equilibrium.

ASSOCIATE. See **matrix, associate.**

ASSOCIATED CORPUSCULAR EMISSION. (Expression used in definition of **roentgen.**) The full complement of secondary charged particles (usually limited to electrons) associated with an **x-ray** or **γ-ray** beam in its pas-

sage through air. The full complement of electrons is obtained after the radiation has traversed sufficient air to bring about equilibrium between the primary photons and secondary electrons. Electronic equilibrium with the secondary photons is intentionally excluded.

ASSOCIATIVE LAW. Addition and multiplication processes obey this law if the following relations hold:

$$a + (b + c) = (a + b) + c;$$

$$(ab)c = a(bc) = abc.$$

ASTABLE (OR FREE-RUNNING). Referring to a **circuit** which has two quasi-stable states. No **trigger** is required; a continuous waveform is generated.

ASTATIC. (1) Without orientation or directional characteristics. (2) A trade name.

ASTATINE. Radioactive element. Symbol At. Atomic number 85.

ASTERISM. One of the characteristic effects sometimes observed in **x-ray spectrograms.** It has, roughly, the shape of a star, and commonly indicates the presence of internal stress in the material under investigation.

ASTON DARK SPACE. In a glow-discharge device, a narrow dark region immediately adjoining the cathode.

ASTON WHOLE NUMBER RULE. The atomic weights of **isotopes** are (very nearly) whole numbers when expressed in **atomic weight units,** and the deviations from the whole numbers of the atomic weights of the elements are due to the presence of several isotopes with different weights.

ASTIGMATIC DIFFERENCE. The distance between the primary and secondary focus of an astigmatic optical system. (See **astigmatic focus.**)

ASTIGMATIC FOCUS. In an astigmatic system some of the bundle of rays from an off-axis point meet in a line perpendicular to a plane containing the point and the **optical axis.** Some meet in a line at a greater image distance which line lies in a plane containing the point and the optical axis. At all other image distances the bundle is an ellipse (or circle). The first line is called the primary or meridianal or tangential focus. The second line is called the secondary or sagittal focus.

ASTIGMATIC PENCIL. A homocentric pencil of light after **refraction** at a large **angle of incidence** is generally no longer homocentric, but is astigmatic, since the projections of the refracted rays do not pass through a common point.

ASTIGMATIC SPECTRAL LINE. The image of the **entrance slit** at the primary focus (see **astigmatic focus**) of an astigmatic **grating.**

ASTIGMATISM. (1) A defect in a lens, including the lens of the eye, in which there is a difference in the **radius of curvature** of the lens as observed in one plane from that observed in another plane. (2) An **aberration** of a lens with spherical surfaces such that the image of a point not lying on the optical axis is a pair of short lines normal to each other and at slightly different distances from the lens. (3) In an **electron-beam tube,** a focus defect in which the electrons in different axial planes come to focus at different points.

ASTRONOMICAL UNIT. A unit of distance principally employed in expressing distances within the **solar system,** but also used to some extent for measuring interstellar distances. Technically defined, one astronomical unit is the mean distance of the **earth** from the **sun.** To express this in miles it becomes necessary to determine the distance of the earth from the sun in miles or in other words, to determine the **solar parallax.** The value accepted at present for the length of the astronomical unit is 92,897,000 miles (149,504,000 kilometers).

ASYMMETRIC. Not symmetric. The term is generally applied only to functions or systems which are neither **symmetric** nor **antisymmetric.**

ASYMMETRIC TOP. A model of a molecule which has no three-fold or higher-fold axis of symmetry, so that during rotation all three principal moments of inertia are in general different. Examples are the water molecule and the ethylene molecule.

ASYMMETRY, INTRAMOLECULAR. Lack of symmetry in the spatial arrangement of the atoms and radicals within the molecule, especially of carbon compounds but also signifi-

cant with other elements. (See **atoms, isomerism.**)

ASYMMETRY POTENTIAL. The **potential difference** between the outside and the inside surface of a hollow **electrode** (usually a glass electrode).

ASYMPTOTE. A straight line related to a curve in such a way that the distance between them approaches zero as both approach infinity. The asymptote is the tangent of the curve at infinity. (See **hyperbola.**)

ATMOLYSIS. The separation of a mixture of gases by means of their relative **diffusibility** through a porous partition, as burned clay. The rates of **diffusion** are inversely proportional to the square roots of the densities of the gases. Hydrogen, thus, is the most diffusible gas.

ATMOMETER. An instrument for measuring **evaporation,** generally that of water into the atmosphere.

ATMOSPHERE. (1) A gaseous envelope surrounding a body, or a mass of gas occupying a region. (2) A standard unit of pressure (see **atmosphere, standard**). (3) The cluster of **impurity atoms** formed around a **dislocation line,** and responsible for **Cottrell hardening.** An atmosphere can follow the motion of the **dislocation** only very slowly, as in very slow **creep.**

ATMOSPHERE, CIRCULATION OF THE. When averaged over long periods of time, local and small-scale irregularities in the atmosphere's motions disappear and a generalized pattern of winds is manifest. There are five latitudinal belts in each hemisphere into which generalized winds can be classified:

(1) The doldrum belt which extends roughly from the equator to 10 or 15° north and south is a belt of light variable winds.

(2) The trade wind belt extends from 10 or 15° north and south to approximately 30° north and south. Trade winds blow from the northeast to east-northeast in the northern hemisphere and from the southeast to east-southeast in the southern hemisphere and are known respectively as the northeast trades and the southeast trades.

(3) A narrow and drifting belt of light variable winds extends about the earth at approximately 30° north and south. This belt is known as the horse latitudes.

(4) Westerly winds with a slight component from the south blow in a relatively wide band from approximately 30° north and south to 60 or 70° north and south. They are known as the prevailing westerlies but in the southern hemisphere are more commonly known as the roaring Forties because of their stronger and more steady character.

(5) The polar area winds tend to blow anticyclonically with an easterly component over each region. (See also **Winds.**)

ATMOSPHERE, CONTROLLED. The use of a gas other than air, such as hydrogen, nitrogen, carbon dioxide, etc., in an apparatus or process which would react with atmospheric oxygen.

ATMOSPHERE, STANDARD. (1) A unit of pressure, defined as the pressure exerted by a column of mercury 760 mm high, having a density of 13.5951 gm cm^{-3} and subject to gravitational attraction of 980.665 dyne gm^{-1}, which is equal to 1.013250×10^6 dyne cm^{-2}. (2) In meteorology, an atmosphere having a sea-level pressure of 1.013250×10^6 dyne cm^{-2} (1,013.25 millibars); a sea-level temperature of 15°C; and a **lapse-rate** of 6.5°C up to 11 km.

ATMOSPHERIC ACOUSTICS. The study of sound propagation and attenuation in the atmosphere, including such problems as sound ranging and signaling, and aircraft noise.

ATMOSPHERIC DUCT. An atmospheric layer which conducts radio-frequency waves in the same manner as a true waveguide under certain conditions of temperature and humidity. Attenuation at certain frequencies is quite low and transmissions may be received at points far outside the usual reception area.

Atmospheric ducts are sometimes referred to as ground-based ducts, since the atmosphere forms one of the boundary surfaces and the earth's surface the other boundary. The effects of atmospheric ducts are more pronounced in the microwave bands, 3000 mc and up, but they do exist at frequencies as low as 20 mc.

ATMOSPHERIC INSTABILITY. The condition in the atmosphere in which vertical movement is prevalent. (See **atmospheric stability, instability and equilibrium.**)

ATMOSPHERIC INTERFERENCE (SPHERICS). The interference caused radio reception by natural electric disturbances in the atmosphere.

ATMOSPHERIC INVERSION. The condition in which the temperature of the atmosphere increases with height, contrary to the usual state of affairs.

ATMOSPHERIC RADIO WAVE. A radio wave that is propagated by reflections in the atmosphere. It may include either or both of the components, **ionospheric wave** and **tropospheric wave.**

ATMOSPHERIC SOUND REFRACTION, CONVECTIVE. The bending of sound rays in the atmosphere due to a gradient in the wind velocity.

ATMOSPHERIC SOUND REFRACTION, TEMPERATURE. The bending of sound rays in the atmosphere due to a temperature gradient (and hence a gradient in the sound velocity).

ATMOSPHERIC STABILITY, INSTABILITY, AND EQUILIBRIUM. Everywhere that air is in motion some vertical perturbations are present. Isolated parcels and currents of air are thus started upward or downward in a layer of surrounding air. The action of the environment on the displaced parcels is a measure of the stability or instability of the air. If the parcel is forced back to its original position, the air is stable and does not favor vertical motions; if the parcel is accelerated in its vertical movement, then the air is unstable and favors vertical motions; if the parcel comes to rest at a new position, neither rising nor falling, then the air is in an equilibrium state.

ATOM. The smallest particle of an **element** which can enter into chemical **combination.** All chemical compounds are formed of atoms, the difference between compounds being attributable to the nature, number, and arrangement of their constituent atoms. For current views of structure, see **atomic structure.**

ATOM, BOHR-SOMMERFELD. The **Bohr theory** of atomic **spectra** postulated an electron moving about the nucleus of its atom in a limited number of circular orbits, with energy changes due to abrupt transitions from one orbit to another accounting for the emission or absorption of radiation. To account for the fine structure of spectra, Sommerfeld also included elliptical orbits, with variations in the shape of the ellipse, to be formulated in terms of two quantum numbers (azimuthal and radial). Moreover, the ellipse of the electronic pathway "precesses" or moves through a series of positions.

ATOM DISINTEGRATION. The **emission** by an atomic nucleus of a particle or particles, or larger fragments, and radiations, resulting in the formation of new atomic species, differing from the original in mass, atomic number, or energy or in more than one of those properties. Disintegration may occur naturally, as in the case of the radioactive **elements,** or may be produced artificially, by bombardment with particles or radiations.

ATOM, EXCITED. An atom which possesses more energy than a normal atom of that species. The additional energy commonly affects the electrons surrounding the atomic nucleus, raising them to higher energy levels.

ATOM, IONIZED. An **ion,** which is an atom that has acquired an electric charge by gain or loss of **electrons** surrounding its **nucleus.**

ATOM, LABELED. A tracer atom which can be detected easily, and which is introduced into a system to study a process or structure.

ATOM, LEWIS-LANGMUIR. A theory of **electron** arrangement in which it was postulated that the number of electrons surrounding the **nucleus** of an atom was equal to the **atomic number;** that the electrons are arranged in various shells, each consisting of electrons having the same orbital dimensions, but that the electrons in successive shells differ in the dimensions of their orbits; that if atoms were considered in order of increasing atomic number, the essential structure of their **electron shells** would be the same, with the numbers of electrons in completed shells being 2, 8, 8, 18, 18, and 32; that the inert nature of the rare gases was due to their possession of completed electron shells, that the chemical properties of other atoms depend upon the number of electrons in their partly-formed outer shells; that since elements whose outermost shells lack one electron of completion would tend strongly to acquire that electron, while elements having only one electron in their outermost shell would tend to lose it;

that such processes in these and other atoms often result in compound formation by such means, whereby the resulting atomic entities, or ions, are joined by the resulting electrostatic forces; and that many of the periodic properties of the elements are explicable by these postulates.

ATOM, NEUTRAL. An **atom** which has no over-all, or resultant, electric charge.

ATOM, NORMAL. An atom which has no over-all electric charge, and in which all the electrons surrounding the nucleus are at their lowest **energy levels.**

ATOM, NUCLEAR. An atomic **nucleus** without surrounding electrons.

ATOM, RADIATING. An atom which is emitting **radiation** during the transition of one or more of its electrons from higher to lower energy states.

ATOM, RECOIL. An atom which undergoes a sudden change or reversal of its direction of motion as the result of the emission by it of a **particle** or **radiation.**

ATOM, RUTHERFORD. A theory of the structure of the atom in which a small **nucleus** concentrates practically all the mass, and has a positive charge equal to the **atomic number.** An equal number of electrons, surrounding the nucleus, fill the major part of the atomic volume. This idea is the basis of the **Bohr-Sommerfeld atom,** and of all subsequent theories.

ATOM, STRIPPED. An atomic **nucleus** without surrounding electrons.

ATOM, UNITED. An entity postulated in atomic studies, e.g., one of the methods of approach to the study of molecular dissociation. In this method of analysis, the nuclei of the atoms forming the molecule are assumed to be brought so close to each other that they form a single atom, with the same number of electrons as the molecule. Such an atom is called a united atom. The analysis then proceeds by assuming that this atom is then split up, until it forms the given molecule.

ATOMIC ABSORPTION COEFFICIENT. See **absorption coefficient, atomic.**

ATOMIC BEAM METHOD. A method of broadening of spectral lines devised to obtain the high resolution necessary for accurate resolution of hyperfine structure components. This method was developed by Jackson and Kuhn (Proc. Roy. Soc. [A] **148,** 335 (1935)) as follows: Atoms evaporated from the surface of a liquid are passed through a long cool tube to produce a beam in which the greatest angle that an atom can make with the axis of the tube is d/l, where d is the diameter of the tube and l is length. Now if these atoms are excited or allowed to absorb energy, and the radiation or absorption is observed by a spectroscope whose line of sight is at right angles to the direction of the atomic ray, then the **Doppler width** of the emitted or absorbed line will be smaller in the ratio of d to l than that of a line emitted by the atoms with their normal random distribution of velocities at the temperature of the liquid from which the atoms are evaporating. (See also **molecular beam.**)

ATOMIC CHARGE. The electrical charge of an **ion** (charged atom) which is equal to the product of the number of electrons the atom has gained or lost in its **ionization,** by the charge on one electron. (See **charge, elementary.**)

ATOMIC CHARGE, EFFECTIVE. The spectra of monovalent atoms may be approximated by a Balmer-like formula in which the charge on the nucleus is reduced by a shielding constant due to the other electrons in the atom. The value of this effective atomic charge will depend on the amount of penetration of the valence electron into the kernel of the atom, i.e., the cloud of electrons between the valence electron and the nucleus.

ATOMIC CORE. An atom stripped of its **valence electrons,** leaving only closed **electron shells** about the **nucleus.**

ATOMIC DISTANCE. The average distance separating the centers of two atoms

ATOMIC ENERGY. (1) The constitutive internal **energy** of the **atom,** which would be absorbed when the atom is formed from its constituent particles, and released when it is broken up into them. This is identical with the **binding energy** and is proportional to the **mass defect.** (2) Energy released as the result of the disintegration of atomic nuclei, particularly in large scale processes.

ATOMIC ENERGY LEVELS. (1) The values of the energy corresponding to the **stationary states** of an isolated atom (2) The set of stationary states in which an atom of a particular species may be found, including the **ground state,** or **normal state,** and the excited states

ATOMIC FACTOR. See **atomic scattering factor.**

ATOMIC FREQUENCY. The vibrational frequency of an **atom,** used particularly with respect to the solid state.

ATOMIC HYPOTHESIS. The theory that all matter is composed of small indivisible particles, called atoms.

ATOMIC KERNEL. An atom which has lost the electrons in its outermost shell (the valency electrons). (Same as **atomic core.**)

ATOMIC MASS. The mass of a neutral atom of a nuclide. It is usually expressed in terms of the physical scale of atomic masses, that is, in atomic mass units **(amu).**

ATOMIC MASS CONVERSION FACTOR. The experimentally determined ratio of the atomic weight unit **(awu)** to the atomic mass unit **(amu).** Because the isotopic composition of natural oxygen varies slightly with its source, the value (1 amu = 0.999728 awu) of this factor is uncertain in the seventh significant figure.

ATOMIC MASS NUMBER. See **mass number.**

ATOMIC MASS UNIT. See **amu.**

ATOMIC NUMBER. The number of protons in an atomic nucleus, or the positive charge of the nucleus, expressed in terms of the **electronic charge.** It is usually denoted by the symbol Z.

ATOMIC NUMBER, EFFECTIVE. A number calculated from the composition and atomic numbers of a compound or mixture. An element of this atomic number would interact with photons in the same way as the compound or mixture Various formulae for this number have been developed, of which the following are perhaps best known:

Spier: Based on theoretical considerations involving absorption and scattering coefficients (*Brit. J. Radiol.* **19,** p. 52, 1946):

$$Z = \text{effective atomic number}$$
$$= (a_1Z_1{}^{2.94} + a_2Z_2{}^{2.94} + \cdots)^{1/2.94}$$

where Z_1, Z_2, etc., are atomic numbers of individual constituents, and a_1, a_2, etc., the fractional electron contents of elements Z_1, Z_2, etc., in the compound.

Fricke and Glasser: Based on theoretical considerations of photoelectron production (Fortsch. a. d. Gebiete der Roentgenstrahlen, **33,** p. 243, 1925):

$$Z = \sqrt[3]{\frac{a_1Z_1{}^4 + a_2Z_2{}^4 \cdots}{a_1Z_1 + a_2Z_2 \cdots}}$$

where Z_1, Z_2, etc., are the atomic numbers of the constituents, and a_1, a_2, etc., their fractions by weight.

ATOMIC ORBITAL. The **wave function** of an electron in an atom. (See **orbital.**)

ATOMIC PARAMETERS. The distances between the various atoms in a **crystal structure,** as determined, for example, by **x-ray analysis.**

ATOMIC PHOTOELECTRIC EFFECT. Quantitative aspects discussed under **Einstein photoelectric equation.**

ATOMIC PLANE. A plane passed through the atoms of a crystal **space lattice,** in accordance with certain rules relating its position to the **crystallographic axes.** (See **Miller indices.**)

ATOMIC POLARIZABILITY (α). The atomic polarizability is the **susceptibility** per atom. If **P** is the polarization per unit volume produced by an electric field **E**, the polarizability χ is given by

$$\mathbf{P} = \chi\epsilon_0\mathbf{E}$$

where ϵ_0 is the permittivity of free space, and the polarizability per atom is $\alpha = \chi/n$, where n is the number of atoms per unit volume.

ATOMIC PROPERTIES. Properties of substances which are due to the nature of the constituent **atoms,** as distinct from those properties due to their arrangement into molecules and solids, etc.

ATOMIC RADIUS. By a comparison of the **crystal structures** of covalent compounds (see **covalence**), an effective radius can be assigned to each type of atom, as if it were a

sphere of a definite size. This radius depends on the type of bonding, and on the **coordination number.** In turn, the ratio of the atomic radii will often decide the crystal structure of a given compound.

ATOMIC RADIUS, NONBONDED. The value of the **atomic radius** corresponding to the closest distance of approach between atoms not united by a bond.

ATOMIC SCATTERING FACTOR. A factor representing the efficiency with which **x-rays** of a given frequency are scattered into a given direction by a given atom, usually measured in terms of the corresponding factor for a point electron. From this factor is constructed the **structure factor** which governs the diffraction of x-rays in the **x-ray analysis** of **crystal structure.** In general, the atomic scattering factor is proportional to the **atomic number.** If the charge density $\rho(\mathbf{r})$ of the electrons at **r** in the atom is known, then the scattering factor for radiation for wavelength λ, incident on a plane normal to the direction **S**, is given by

$$f = \int \rho(\mathbf{r}) e^{i(2\pi/\lambda)\mathbf{r}\cdot\mathbf{S}} d\tau$$

taken through the volume of the atom.

ATOMIC SOLUTION DIFFUSION. One cause of **internal friction** in **solid solutions** is the diffusion of the constituent atoms.

ATOMIC SPECIES. A distinctive type of atom. The basis of differentiation between atoms is (1) mass, (2) **atomic number**, or number of positive nuclear charges, (3) nuclear excitation energy. The reason for recognizing this third class is because certain atoms are known, chiefly among those obtained by artificial transmutation, which have the same atomic (isotopic) mass and atomic number, but differ in energetics. (See **nuclear isotope.**)

ATOMIC STATE, METASTABLE. An excited atomic energy level wherein the atom cannot give up its energy in the form of radiation but must ultimately return to the normal state by some other process.

ATOMIC STATE, MEAN LIFE OF AN. The time τ after which the number of atoms left in the given atomic state is $1/e$ of the original number. The time is given by the expression:

$$\tau = \frac{1}{A_{nm}} \quad \text{or} \quad \frac{1}{\sum_m A_{nm}}$$

where A_{nm} is the **Einstein transition probability** of spontaneous emission, n is the initial state, m, the final state.

ATOMIC SPECTRUM. See **spectrum, atomic.**

ATOMIC STRUCTURE. According to current views, an atom consists of a number of **electrons** moving in the electrical field of the positive charge of a massive nucleus. Because of the small dimensions of the system, it is impossible to ascribe exact orbits to the electrons. Only the language of **quantum mechanics** suffices to describe an atom, in terms of **wave functions** which measure the density of the electronic cloud surrounding the nucleus. An isolated atom can only exist in discrete **energy states** or **energy levels;** transitions between these are accompanied by the emission or absorption of monochromatic radiant energy.

ATOMIC SUSCEPTIBILITY. The change in **magnetic moment** of one gram-atom of a substance produced by the application of a magnetic field of unit strength.

ATOMIC THEORY. The assumption that matter is not infinitely divisible but is composed of ultimate particles called atoms. The hypothesis was enunciated by John Dalton in 1803, but the idea dates back to the Greek philosophers.

ATOMIC TRANSMUTATION. The changing of an **atom** into an atom of different **atomic number** or, in other words, into an atom of a different **element.** The process of transmutation occurs in nature in the course of the disintegration of the various radioactive elements and may also be effected by artificial means, such as by bombardment with **neutrons, α-particles, γ-radiations,** etc.

ATOMIC WEIGHT UNIT. See **awu.**

ATOMIC VOLUME. A numerical result obtained by dividing the atomic weight of an element by its density. This quantity, when plotted against **atomic number,** exhibits a striking periodicity.

ATOMIC WEIGHT. The weight of an atom of any element, the weight of the oxygen atom

being taken as 16. The atomic weight is also called the equivalent weight or the relative weight. Since many elements, as they commonly occur in nature, are mixtures of **isotopes,** the accepted values of their atomic weights are in reality mean values of the isotopic atomic weights of the various isotopes present. The atomic weight, as defined above, is often called the "chemical atomic weight," taking as its basis a value of 16, for ordinary atmospheric oxygen. Since atmospheric oxygen consists of a mixture of 3 different isotopes, a "physical atomic weight" scale has been established which assigns to the lowest mass isotope the value 16.

ATOMIZATION. The breaking-up of a liquid into small droplets, usually in a high-speed jet or film.

ATR. Abbreviation for anti-transmit-receive switch.

ATTENUATION. In its most general sense, attenuation is reduction in concentration, density or effectiveness. In radiation theory, attenuation is used to express the reduction in flux density, or power per unit area, with distance from the source; the reduction being due to **absorption** and/or **scattering.** In the most common usage, attenuation does not include the inverse-square decrease of intensity of radiation with distance from the source. The same restriction applies to the use of the term in nuclear physics, where attenuation is the reduction in the intensity of radiation on passage through matter where the effect is usually due to **absorption** and **scattering.**

ATTENUATION BAND. See **rejection band.**

ATTENUATION CONSTANT. For a traveling plane wave at a given frequency, the rate of exponential decrease of the amplitude of a field component (or of the voltage or current) in the direction of propagation, in **nepers** or **decibels** per unit length.

ATTENUATION CONSTANT (IMAGE). The real part of the **transfer constant.**

ATTENUATION DISTORTION. See **amplitude distortion.**

ATTENUATION EQUALIZER. An **equalizer** used to compensate for **amplitude-frequency distortion** in a system.

ATTENUATION FACTOR. (1) A measure of the opacity of a layer of material for radiation traversing it. It is equal to I_0/I, in which I_0 and I are the intensities of the incident and emergent radiation, respectively. In the usual sense of exponential absorption

$$I = I_0e^{-\mu x}$$

where x is the thickness of the material and μ is the **absorption coefficient.** (2) A meaning similar to that in (1) is current in electrical circuit applications, where the attenuation factor is the ratio of the input current to the output current of a line or network (3) For acoustic attenuation factor, see **absorption coefficient, amplitude.**

ATTENUATION-FREQUENCY DISTORTION. See **amplitude-frequency distortion.**

ATTENUATION RATIO. The magnitude of the propagation ratio.

ATTENUATION, SIDEBAND. That form of **attenuation** in which the transmitted relative amplitude of some component(s) of a **modulated signal** (excluding the **carrier**) is smaller than that produced by the **modulation** process.

ATTENUATION, VOLTAGE (TRANSDUCER). The ratio of the magnitude of the voltage across the input of the **transducer** to the magnitude of the voltage delivered to a specified load impedance connected to the transducer. If the input and/or output power consist of more than one component, such as multifrequency signal or noise, then the particular components used and their weighting must be specified. By an extension of the term "decibel," this attenuation is often expressed in decibels by multiplying its common logarithm by 20.

ATTENUATOR (PAD). A network designed to introduce a definite loss in a circuit. It is designed so the **impedance** of the attenuator will match the impedance of the circuit to which it is connected, often being connected between two circuits of different impedance and serving as a matching network as well as an attenuator. It is distinguished from a simple resistance in that the impedance of an attenuator does not change for various values of its attenuation. It is a valuable unit in making many laboratory tests on communications equipment where it is used to adjust the

outputs of two pieces of apparatus or for two different conditions so the relative merits may be determined from the attenuator setting In much communication work it is desirable to transmit power at a higher level than will be used in order to overcome circuit noises, and then to reduce it to the proper value at the receiving end by a pad It is usually calibrated in **decibels** and thus indicates the attenuation introduced by it.

ATTENUATOR, CHIMNEY. One form of coaxial-line attenuator which received its name from the appearance of the stub lines.

ATTENUATOR, COAXIAL LINE. An **attenuator** for use in a coaxial line. It may be fixed or variable

ATTENUATOR, FLAP OR FIN. A waveguide **attenuator** in which a fin or flap of conducting material is moved into the guide in such a manner as to cause power absorption

ATTENUATOR, TRANSVERSE FILM. An **attenuator** consisting of a conducting film placed transverse to the axis of a **waveguide.**

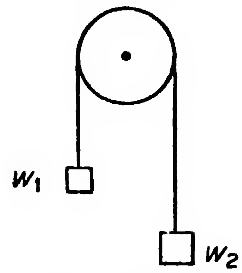
ATTRACTION, ELECTRICAL. The force between electric charges of opposite sign, having a magnitude given by the **Coulomb law.**

ATTRACTION, GRAVITATIONAL. According to the **Newton law of universal gravitation,** every mass in the universe attracts every other mass with a force directly proportional to the product of the masses and inversely proportional to the distance between their centers of mass This attraction is illustrated in the solar system by the attraction exerted by the sun upon the planets and by the individual planets upon each other

ATTRACTION, MAGNETIC. A force exerted by a magnetized body upon another capable of **magnetization,** as of an iron magnet upon a piece of iron The force between two magnets may be an attraction or a repulsion, depending upon orientation.

ATTRACTIVE FORCES IN LIQUIDS. With the exception of liquid rare gases, a liquid molecule exerts on its neighbors an attractive force which falls off very rapidly with distance and which is negligible for spacings more than a few molecular diameters The attractive forces in liquid rare gases are of the van der Waals (see **van der Waals forces**) type, varying inversely as the seventh power of the distance, but ordinary liquid molecules attract one another with a force that falls off much more rapidly.

ATWOOD MACHINE. A device consisting of a wheel or pulley over which is passed an inextensible cord connecting two weights. It



Atwood Machine

is often used to demonstrate motion of a system under an external uniform force in accordance with the **Newton Second Law of Motion.** It can be used to determine acceleration of gravity.

AUDIBILITY, LIMITS OF. The thresholds of hearing the minimum effective sound pressure that can be heard at a specified frequency forms the lower limit (minimum audibility or threshold pressure), the minimum effective sound pressure that causes feeling or pain in the ear forms the upper limit (threshold of feeling) (See **sound pressure, effective; audibility, threshold of;** and **feeling, threshold of.**)

AUDIBILITY, MINIMUM. See **audibility, threshold of.**

AUDIBILITY, THRESHOLD OF (THRESHOLD OF DETECTABILITY). For a specified signal, the minimum effective sound pressure of the signal that is capable of evoking an auditory sensation in a specified fraction of the trials The characteristics of the signal, the manner in which it is presented to the listener, and the point at which the sound pressure is measured should be specified.

Unless otherwise indicated, the ambient noise reaching the ears is assumed to be negligible. The threshold may be expressed in **decibels** relative to 0 0002 **microbar** or to 1 microbar. Instead of the method of constant stimuli, which is implied by the phrase "in a specified fraction of the trials," another psychophysical method (which should be specified) may be employed.

AUDIO. Pertaining to sound or hearing. The word "audio" may be used as a modifier to indicate a device or system intended to operate at **audio frequencies.**

AUDIO DISTORTION. See **audio** and **distortion.**

AUDIO FREQUENCY. Any frequency corresponding to a normally audible sound wave Audio frequencies range roughly from 15 to 20,000 cycles per second

AUDIO-FREQUENCY HARMONIC DISTORTION. The generation in a system of integral multiples of a single audio-frequency input signal

AUDIO-FREQUENCY PEAK LIMITER. A circuit used in an audio-frequency system to cut off peaks that exceed a predetermined value.

AUDIOGRAM. A graph showing **hearing loss,** percent hearing loss, or percent hearing (see **hearing, percent**) as a function of frequency.

AUDIOGRAM, MASKING. A graphical presentation of the **masking** due to a stated noise This is plotted, in **decibels,** as a function of the frequency of the masked tone

AUDIOMETER. An instrument for measuring hearing acuity Measurements may be made with speech signals, usually recorded, or with tone signals.

AUDIOMETRY. The study of hearing acuity by means of **audiometers.**

AUDION. The original three-element **vacuum tube** invented by DeForest.

AUDITORY CANAL. The canal connecting the external ear (pinna) and the ear drum.

AUDITORY LOCALIZATION. The ability of the ear to locate the apparent direction of sound sources, especially by means of the **binaural effect.**

AUDITORY SENSATION AREA. (1) The region enclosed by the curves defining the threshold of feeling and the threshold of audibility as functions of frequency (see **feeling, threshold of,** and **audibility, threshold of**). (2) The part of the brain (temporal lobe of the cortex) which is responsive to auditory stimuli.

AUGER COEFFICIENT. The ratio of **Auger yield** to **fluorescence yield,** which is also expressed quantitatively as the ratio of the number of Auger electrons to the number of x-ray photons ejected from a large number of similarly excited atoms. (See **Auger effect.**)

AUGER EFFECT. A nonradiative transition of an atom from an excited electronic energy state to a lower state with the emission of an electron. The term usually refers to the x-ray region of energy states. The final state corresponds to one higher degree of ionization than does the initial state. The effect is an alternative process to the transition to a lower state having the same degree of ionization with the emission of an x-ray photon, and thus is analogous to the **internal conversion** of a nuclear transition The ejected electron has kinetic energy equal to the difference between the energy of the x-ray photon of the corresponding **radiative transition,** and the binding energy of the ejected electron

More explicitly, the Auger process takes place when two energy levels of an atomic system which belong to different term series, happen to lie close together They then influence each other, there is a shift of the two levels in the sense of a repulsion, and there is a mixture of the **eigenfunctions** of the two states When one term in a discrete series has the same energy as a term of a continuous term spectrum, all the higher terms of the series have the same energy as correspondingly higher terms of the continuous range, and therefore, all the higher terms of this series may be perturbed. In such a perturbation by a continuous term the shift of the originally discrete level can assume a continuous series of values That is, the level becomes diffuse; the atom or molecule can assume all energy values in a more or less narrow region (depending on the strength of the perturbation).

As in the case of ordinary perturbations a mixing of the eigenfunctions takes place here also, so that the true state is a hybrid. Part of the time the system is in the discrete "state," part of the time it is in the continuous "state." However, a continuous state means a splitting of the system and a flying apart of the parts with more or less kinetic energy (the eigenfunction is an outgoing, spherical wave). Therefore, when, as a result of the mutual

perturbation, the system has once gone from the discrete into the continuous "state," it cannot return to the discrete "state," since the parts are soon widely separated from each other. Thus, if an atomic system is transferred to such a diffuse state—for example, by light absorption—it undergoes a radiationless decomposition after a certain lifetime.

AUGER EFFECT, CRITERIA FOR. (1) Radiationless decomposition of the system (ionization or dissociation) after a mean life τ_l—that is, with a probability $\gamma = 1/\tau_l$. (2) Broadening of the discrete levels under consideration and correspondingly of the spectral lines which have these levels as upper or lower states. (3) Weakening of the emission from these levels, since only the molecules that do not decompose can radiate.

AUGER ELECTRON. An electron ejected from an excited atom in the **Auger effect.**

AUGER SHOWER. A shower of **Auger electrons**, a term now applied to any extensive shower.

AUGER YIELD. The Auger yield for a given excited state of an atom of a particular element is the probability of deexcitation by the **Auger effect** rather than by x-ray emission; it is the difference between unity and the fluorescence yield for that state, and also equals the sum of the Auger yields for the various possible Auger transitions from that state.

AUGHEY SPARK CHAMBER (GAS TRANSPORT ELECTRODES). An electrical spark is produced between two hollow tubular electrodes. A gas passed through the electrodes into the space where the spark occurs will be excited and caused to emit its characteristic spectrum. Traces of contamination in the gas, such as dust particles, will be efficiently excited so that their spectrum may be observed.

AUGMENTATION DISTANCE. The distance between the extrapolated boundary and true boundary of a nuclear **reactor.** Also known as extrapolation distance.

AURAL HARMONIC. A **harmonic** generated in the auditory mechanism.

AURAL TRANSMITTER. The radio equipment for the transmission of the aural signals only.

AUREOLE. The hazy, less luminous outer portion of an **electric arc**, often of a different spectrum from that of the core.

AURORAL LINE. A green line in the spectrum of the aurora borealis at wavelength 5577 Å due to a **forbidden transition** in oxygen.

AUTOCOLLIMATOR. (1) A device by which a **lens** makes diverging light from a slit parallel, and then after the parallel light has passed through a prism to a mirror and been reflected back through the prism, the same lens brings the light to a focus at an **exit slit.** (2) A telescope provided with a **reticle** so graduated that angles subtended by distant objects may be read directly. (3) A convex **mirror** placed at the focus of the principal mirror of a reflecting **telescope** and of such curvature that the light after reflection leaves the telescope as a parallel beam.

AUTOCONVECTION LAPSE RATE. Undisturbed air will remain stratified even though the **lapse rate** exceeds the dry-adiabatic rate of 5.5°F per 1000 ft. If the lapse rate becomes sufficiently large, density of the air will increase with altitude and will overturn. This critical lapse rate is 34.17°C per km or very nearly 19°F per 1000 ft.

AUTODYNE DETECTOR. See **beatnote detector.**

AUTOELECTRIC EFFECT. The emission of electrons from a cold cathode due to the application of an intense electric field at its surface.

AUTOELECTRIC EMISSION. See **autoelectric effect.**

AUTOIONIZATION OR PREIONIZATION. An atom which is in a discrete energy state above the ionization point can ionize itself automatically with no change in its angular momentum vectors if there is a continuum with exactly the same characteristics.

AUTOMATIC CONTRAST CONTROL. In television receivers, **automatic gain control** of the i-f and r-f video amplifiers. Thus the second detector output amplitude is essentially constant, which results in constant picture contrast.

AUTOMATIC CONTROL SYSTEM. Any operable combination of one or more **automa-**

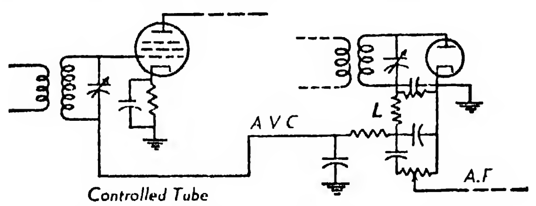
tic controls connected in closed loops with one or more processes.

AUTOMATIC CONTROLLER. A device which measures the value of a variable quantity or condition, and operates to correct or limit deviation of this measured value from a selected reference. It includes both the measuring means and the controlling means.

AUTOMATIC FREQUENCY CONTROL. An arrangement whereby the **frequency** of an **oscillator** is automatically maintained within specified limits.

AUTOMATIC GAIN CONTROL. A circuit arrangement which adjusts the **gain** in a specified manner in response to changes in input. Also called **automatic volume control.**

AUTOMATIC VOLUME CONTROL. An automatic volume control circuit is incorporated in a **radio receiver** to maintain the amplitude of the signal applied to the **detector** as nearly constant as possible and thus correct for variations in signal strength caused by **fading.** When a modulated radio-frequency wave is detected the output contains a d-c component which has a magnitude proportional to the amplitude of the **carrier** impressed on the detector. Other components (af and rf) are filtered out and this d-c voltage is applied as **bias** to the **variable mu** radio



Simple automatic volume control circuit

frequency amplifiers. The figure illustrates the essential components of such a system, the resistance and capacitance units indicated as L serving to separate the various components of the detector output and route them to the proper parts of the complete receiver. The d-c for the avc is fed, as indicated, to the grid of the rf tubes, usually all being so biased although only one is shown. Thus a high value of applied signal gives a high value of d-c output which is applied to the variable mu tube, making its grid more negative and thus decreasing its gain and reducing the signal applied to the detector. A low value of carrier gives a lower value of d-c which means less negative bias on the rf tube, hence more gain and increased signal to the detector.

AUTOMATIC VOLUME CONTROL, DELAY. See **delay automatic-volume-control.**

AUTORADIOGRAPH (RADIOAUTOGRAPH). Record of radiation from radioactive material in an object, made by placing its surface in close proximity to a photographic emulsion.

AUTOSYN. A trade name for **synchro.**

AUXILIARY EQUATION. Using the symbol $D = d/dx$, a given linear **differential equation** with constant coefficients may be written in the form

$$D^n y + a_1 D^{n-1} y + \cdots + a_n y = 0$$

The auxiliary equation is

$$(D - r_1)(D - r_2) \cdots (D - r_n)y = 0$$

where the r's are roots of the algebraic equation

$$r^n + a_1 r^{n-1} + a_2 r^{n-2} + \cdots + a_n = 0.$$

The general solution of the original differential equation is then

$$y = \sum_i c_i e^{r_i x}$$

the c_i's being arbitrary constants, provided the roots are all unequal. If one of them, r_g is repeated g times the corresponding terms in the general solution of the differential equation are replaced by $c_g(1 + a_1 x + a_2 x^2 + \cdots + a_{g-1} x^{g-1})e^{r_g x}$. Imaginary roots, if they occur, have the form $r_\pm = A \pm iB$ and the term in the solution becomes $e^{Ax}(c_+ \cos Bx + c_- \sin Bx)$.

AUXOCHROME. A **chromophore** which has a noteworthy effect on the wavelength at which absorption occurs.

AUXOMETER OR AUXIOMETER. An apparatus for measuring the **magnifying power** of a lens or any optical system.

AVAILABLE ENERGY. Energy which can be converted into mechanical work by means at human disposal. (See **free energy.**)

AVAILABLE POWER. (1) Of a linear source of electric energy, the quotient of the mean square of the open-circuit terminal voltage of the source, divided by four times the

resistive component of the **internal impedance** of the source. The available power would be delivered to a load impedance that is the conjugate of the internal impedance of the source, and is the maximum power that can be delivered by that source.

(2) From a **generator** or an electric **transducer,** the power that would be delivered to the output external termination of the generator or transducer if the **admittance** of the external termination were the conjugate of the output **driving-point admittance** of the generator or transducer.

(3) The available power of a sound field, with respect to a given object placed in it, is the power which would be abstracted from the acoustic medium by an ideal transducer having the same dimensions and the same orientation as the given object. The dimensions and their orientation with respect to the sound field should be specified. The commonly used unit is the erg per second, but the available power may also be expressed in watts. The acoustic power available to an electroacoustic transducer, in a plane-wave sound field of given frequency, is the product of the free-field sound intensity by the effective area of the transducer. For this purpose the effective area of an electroacoustic transducer, for which the surface velocity distribution is independent of the manner of excitation of the transducer, is $1/4\pi$ times the product of the receiving **directivity factor,** by the square of the wavelength of a free progressive wave (see **wave, progressive**) in the medium. The commonly used unit is the square centimeter. If the physical dimensions of the transducer are small in comparison with the wavelength, the directivity factor is near unity, and the effective area varies inversely as the square of the frequency. If the physical dimensions are large in comparison with the wavelength, the directivity factor is nearly proportional to the square of the frequency, and the effective area approaches the actual area of the active face of the transducer.

AVAILABLE POWER EFFICIENCY. Of an electroacoustic transducer used for sound reception, the ratio of the electric power available at the electric terminals of the **transducer** to the **acoustic power** available to the transducer. For an electroacoustic transducer which obeys the **reciprocity principle,** the available power efficiency in sound reception is equal to the transmitting efficiency. In a given narrow-frequency band, the available power efficiency is numerically equal to the fraction of the open-circuit mean-square thermal noise voltage present at the electric terminals which is contributed by thermal noise in the acoustic medium.

AVAILABLE POWER RESPONSE. Of an electroacoustic **transducer** used for sound emission, the ratio of the mean-square sound pressure apparent at a distance of 1 meter in a specified direction from the effective acoustic center of the transducer to the available electric power from the source. The available power response is usually expressed in decibels above the reference response of 1 microbar squared per watt of available electric power. The sound pressure apparent at a distance of 1 meter is determined by multiplying the sound pressure observed at a remote point where the sound field is spherically divergent by the ratio of the distance of that point, in meters, from the effective **acoustic center** of the transducer, to the reference distance of 1 meter. The available power response is a function not only of the transducer but also of some source impedance, either actual or hypothetical, the value of which must be specified.

AVALANCHE. A term used in **counter** technology to describe the process which is essentially a cascade multiplication of ions. In this process, an ion produces another ion by **collision,** and the new and original ions produce still others by further collisions, resulting finally in an "avalanche" of ions (or electrons). The terms "cumulative ionization" and "cascade" are also used to describe this process.

AVALANCHE EFFECT. (1) The condition which exists in a **Townsend discharge** when the applied voltage is sufficient to cause electrons to ionize gas molecules upon collision, thus releasing new electrons. This creates a cumulative increase or **avalanche** of current. The discharge is thus self-maintained. (2) Sometimes applied to the **Zener effect** in semiconductors.

AVC. Abbreviation for **automatic volume control.**

AVE. Abbreviation for **automatic volume expansion.**

AVERAGE. Defined for a quantity Q by

$$\bar{Q} = \frac{\Sigma w(a_1, \cdots, a_s)Q(a_1, \cdots, a_s)}{\Sigma w(a_1, \cdots, a_s)}$$

where w is the **weighting function.** The ordinary average is obtained by taking $w = 1$ so

$$\bar{Q} = \frac{\Sigma Q(a_1, \cdots, a_s)}{n}.$$

When Q and w are continuous,

$$\bar{Q} = \frac{\int_\tau w(x_1, \cdots, x_s)Q(x_1, \cdots, x_s)dx_1 \cdots dx_s}{\int_\tau w(x_1, \cdots, x_s)dx_1 \cdots dx_s}$$

where τ is the domain of definition of Q and w.

AVERAGE ABSOLUTE PULSE AMPLITUDE. See **pulse amplitude, average absolute.**

AVERAGE DEVIATION. The average deviation (A.D.) of a number of like quantities X_j is the average of the absolute departures of their individual values from their mean

$$\text{A.D.} = \frac{\sum_{j=1}^{n} | X_j - \bar{X} |}{n},$$

where the mean

$$\bar{X} = \frac{\sum_{j=1}^{n} X_j}{n}.$$

The A.D. is a measure of the expected departure of any single observation of a series from the "true" value which would be obtained by the averaging of an infinite series of observations. The average deviation of the mean (a.d.) is

$$\text{a.d.} = \text{A.D.}/\sqrt{n-1}$$

A.D. and a.d. are related to other measures of uncertainty if the individual values are distributed according to a particular rule, such as the normal error function in the **Gaussian error function.**

AVERAGE ELECTRODE CURRENT. See **electrode current, average.**

AVERAGE SPEECH POWER. See **speech power, average.**

AVERAGES, METHOD OF. A procedure for evaluating the numerical coefficients of a **polynomial equation.** Suppose there are n measurements of some physical quantity y and that a polynomial of degree $m < n$ is to be used for expressing the dependence of y on some other quantity x, so that $y = A + Bx + Cx^2 + \cdots + Mx^m$. Divide the measurements into $(m + 1)$-groups, add the equations in each group to obtain a set of $(m + 1)$-simultaneous equations and solve them for the desired numbers $A, B, C, \cdots, M$.

AVOGADRO CONSTANT. The number of molecules contained in one **mole** or gram-molecular weight of a substance. The presently-accepted value of the Avogadro constant, which is usually denoted by N, is $(6.02544 \pm 0.00011) \times 10^{23}$/gm mole (phys.). This is the least-squares adjusted value.

AVOGADRO HYPOTHESIS. (Avogadro rule.) Avogadro, in 1811, enunciated the rule that equal volumes of gases under like conditions of temperature and pressure contain equal numbers of molecules.

AVOGADRO NUMBER. See **Avogadro constant.**

AWBERG AND GRIFFITHS METHOD FOR LATENT HEAT OF VAPORIZATION. A continuous-flow method in which the heat of evaporation of the liquid under investigation is transmitted to a constant stream of water, whose temperature is raised a measured amount.

AWU. The atomic weight unit, which is one-sixteenth of the weighted mean of the masses of the neutral atoms of oxygen of isotopic composition of that found in fresh lake or rain-water.

$$1\ awu = 1.660 \times 10^{-24}\ \text{gm}.$$

AXIAL MAGNIFICATION. The ratio of the interval between two adjacent **image points** on the axis of an optical instrument to the interval between the conjugate **object points.**

AXIAL RATIO (OF A WAVE GUIDE). The ratio of the major axis to the minor axis of the **polarization ellipse.**

AXIAL VECTOR. Pseudo-vector. The term is usually applied to vectors in three dimensions. An axial vector thus transforms like an

ordinary or **polar vector** under rotations but changes sign, with respect to a polar vector, under an orthogonal transformation of determinant -1.

AXICON. An optical component which has the property that a point source on its axis of revolution is imaged to a range of points along its axis. Axicons do not, therefore, have a definite **focal length.**

AXIOTRON. A high-vacuum, thermionic **diode** in which the magnetic field produced by the filament current exhibits control over the anode current.

AXIS. A line so situated that various parts of an object are symmetrically located in relation to it. Also the line passing through the origin of a coordinate system which corresponds to all points of a given variable when other variables are zero. Thus, in two dimensions, the X-axis is the locus of all points whose Y-coordinate is zero. (See also **ellipse, hyperbola, parabola.**)

AXIS, INSTANTANEOUS. In rigid body motion, the instantaneous axis is the axis perpendicular to the plane of the motion which passes through that point or those points of a body which are instantaneously at rest. For a cylinder rolling down an inclined plane without slipping, the instantaneous axis is the line of contact between cylinder and plane.

AXIS (AXES) OF ROTATION, FIXED. The locus of points of a system along a straight line which remain stationary when rest of system undergoes rotational motion. (See **rotation.**)

AXIS, OPTIC. A direction through a doubly-refracting crystal along which no **double refraction** occurs. A uniaxial crystal has one such direction, a biaxial has two such directions. (See **crystal, uniaxial,** and **crystal biaxial.**)

AXIS, OPTICAL. The line through the **foci** and the **vertices** of the optical surfaces. Commonly, the surfaces of lenses and mirrors **are** figures of revolution about the optical **axis.** Normally, the parts of an optical system are all coaxial.

AXONOMETRY. Measurement of axes, especially in crystals.

AZEOTROPE. A mixture with a constant boiling point. A negative azeotrope has a minimum, a positive, a maximum boiling point.

AZIMUTH ANGLE. For plane-**polarized light** incident on the surface of a dielectric, the angle between the plane of vibration and the normal to the plane of incidence. This same word applies to incident, reflected and refracted light.

AZIMUTHAL QUANTUM NUMBER. An integer obtained in quantizing the angular **momentum** of a particle, such as an electron, moving in an elliptical path. The total momentum is resolved into components, one directed radially and the other tangentially to the orbit. The latter has values given by the expression $hk/2\pi$, in which h is the **Planck** constant, and k is the azimuthal quantum number.

B

B. (1) Breadth or width (b). (2) Element boron (B). (3) "Boils at" (b). (4) Second van der Waals constant (b). (5) Effective film thickness (B). (6) Brightness or luminance (B). (7) Wien displacement constant (b). (8) Volume modulus of elasticity (B). (9) Factor in Richardson-Dushman equation (b). (10) Susceptance (B or b). (11) Second Couchy constant (B). (12) Magnetic flux density (**B**). (13) Band head (B).

B, B+, B -. Letter and symbols used to identify the high-voltage plate supply for **vacuum tubes.**

B BATTERY. The power source for the anode circuit of an electronic device which is battery-operated.

BABBLE. The aggregate **cross talk** from a large number of disturbing channels.

BABINET ABSORPTION RULE. Positive uniaxial crystals (see **crystal, uniaxial**) have greater absorption for the extraordinary component, while negative crytals have greater absorption for the ordinary component of the light doubly-refracted by them.

BABINET COMPENSATOR. See **compensator.**

BABINET-JAMIN COMPENSATOR. Jamin introduced the controlled motion of one prism with respect to the other in the Babinet **compensator.**

BABO, LAW OF. The addition of a non-volatile solid to a liquid in which it is soluble lowers the **vapor pressure** of the solvent in proportion to the amount of substance dissolved.

BACKFIRE. Another name for **arc back.**

BACK FOCAL LENGTH. The distance from the back surface of a lens to the second **focal point.** Its reciprocal is sometimes called the vertex power or the effective power of a lens.

BACKGROUND. A general term for the totality of the effects that are always present in physical apparatus, and above which a phenomenon must show itself in order to be measured. Such unrelated effects include the unwanted counts or currents from **cosmic rays** in electrical apparatus for measurement of radioactivity, developable grains on photographic plates that are unrelated to the phenomena investigated, noise in acoustical apparatus, and many others.

BACKGROUND CONTROLS. The three individual color brightness controls on color television receivers.

BACKGROUND COUNTS. (1) Counts caused by any agency other than the one which it is desired to detect. (2) Counts caused by radiation coming from sources external to the **counter tube** other than the source being measured, or by radioactive contamination of the counter tube itself. (I.R.E. Definition.)

BACKGROUND NOISE. See **noise, background.**

BACKHEATING. In **magnetrons,** the increase in cathode temperature due to high-velocity electrons being returned to its surface. It may be sufficiently severe to cause **burnout.**

BACK PORCH. In television, that portion of a **composite picture signal** which lies between the trailing edge of a horizontal sync pulse and the trailing edge of the corresponding blanking pulse. The **color burst,** if present, is not considered part of the back porch.

BACK-PORCH EFFECT. The continuation of **collector current** in a **transistor** for a short time after the input signal has become zero due to a storage of minority carriers (see **carrier, minority**) in the base region. The effect is most noticeable for large signals and is also apparent in **junction diodes.**

BACK SCATTERING. The deflection of particles or of radiation by **scattering** proc-

esses through angles greater than 90° with respect to the original direction of motion.

BACK-SCATTERING COEFFICIENT B (ECHOING AREA). For an incident plane wave, the back-scattering coefficient B is 4π times the ratio of the reflected power per unit solid angle (Φ_r) in the direction of the source divided by the power per unit area (W_i) in the incident wave:

$$B = 4\pi \frac{\Phi_r}{W_i} = 4\pi r^2 \frac{W_r}{W_i},$$

where W_r is the power per unit area at distance r. For large objects, the back-scattering coefficient of an object is approximately the product of its interception area by its scattering gain in the direction of the source, where the interception area is the projected geometrical area and the scattering gain is the reradiated power gain relative to an isotropic radiator

BACK-SHUNT KEYING. See **keying, back-shunt.**

BACK-TO-BACK CONNECTION. The connection of a pair of tubes (usually **ignitrons** or **thyratrons**) in a manner which will permit control of alternating current rather than direct current. The anode of one tube is connected to the cathode of the other, and vice-versa. Thus, one tube may function on each half-cycle of supply voltage.

BACK-WALL PHOTOVOLTAIC CELL. A **photovoltaic cell** in which the light must pass through the front electrode and a **semiconductor layer** before reaching the **barrier layer.**

BACKWARD WAVE. See **wave, backward.**

BACK WAVE. See **wave, back;** and **wave, spacing.**

BADGER RULE. An empirical relation between the **force constants** and vibrational frequencies of the electronic states of diatomic molecules of the form

$$k_e(r_e - d_{ij})^3 = C^{11}$$

where k_e is the force constant, r_e is the internuclear distance, d_{ij} is a constant that is different for each type of molecule (it is 0.68A if both atoms are in the first row of the periodic system, 1.25A if they are in the second, etc.) and C^{11} may be taken as the same for all molecules (= 1.86 if k_e is in 100,000 dynes/cm and r_e and d_{ij} in A).

The Badger rule may readily be applied to polyatomic molecules.

BAFFLE. A shielding structure or partition used to increase the effective length of the external transmission path between two points in an acoustic system as, for example, between the front and back of an electroacoustic **transducer.**

BAIRD DENSITOMETER. A direct reading instrument for measuring the **density** of a photographic plate. Made by Baird Associates.

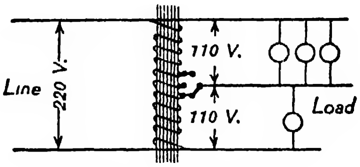
BALANCE. (1) A condition of partial or complete equilibrium or adjustment. (See **balance, mechanical.**) (2) A well-known instrument used in weighing. While any type of "scales" used for weighing may properly be called a balance, the term usually refers to the equal-arm balance familiar in every laboratory.

The dynamics of this instrument is relatively simple unless the pans are allowed to oscillate independently of the beam, a condition which should be carefully avoided while taking readings The balance may then be treated as a gravity pendulum suspended from the central knife edge or pivot, the pans and their loads being regarded as concentrated at the end knife edges Any slight excess weight Δw on one pan causes a change in the equilibrium position The "sensitiveness" of the balance is appropriately expressed as the change in the equilibrium pointer reading per unit excess weight. More convenient in practical work is the reciprocal of the sensitiveness, which may be called the "stability" (3) An electrical network is in a condition of balance when it is so adjusted that an emf in one branch produces no current in another branch

BALANCE, CHAIN. A **balance** in which the smaller weights (commonly below 100 mg) are applied by raising or lowering a chain attached to the beam, which is accomplished by moving the other end of the chain along a vertical scale.

BALANCE COIL. A balance coil is a coil for supplying a three-wire circuit from a two-wire circuit. A 220-volt single-phase line, for example, can be used to supply two 110-volt

circuits consisting of three wires, one of which is a common intermediate wire. The voltage between the intermediate wire and either of the outside ones is 110 volts. If the loads on



Balance coil for a-c

the two 110-volt circuits are unequal, the voltage can be balanced by an adjustment of the central tap point at the balance coil. A balance coil is frequently an **auto-transformer** having only one coil, connections at the ends of the coil, and an intermediate connection.

In d-c circuits the balance coil is used in conjunction with the **generator** to obtain a three-wire system. The generator windings are tapped at two diametrically opposite points and these taps are connected to the ends of a balance coil. The third wire for the system is obtained by connection to the center of the balance coil. Some manufacturers build the coil in the spider of the **armature** and bring out the center connection through a **slip ring** and **brush** while other manufacturers bring out the two tap connections on the armature through a pair of rings and brushes, mounting the balance coil outside the generator. The coil presents a high impedance to the uncommutated a-c from the armature, but provides a d-c center-tap.

BALANCE, DAMPED. A balance equipped with means for damping the to-and-fro movements of the suspended system, so that the pointer comes to rest more rapidly. A magnetic system or a piston in a close-fitting cylinder are often used for the damping.

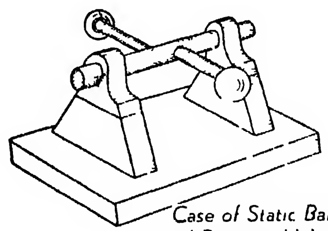
BALANCE, DYNAMIC. See **balance, mechanical.**

BALANCE, ELECTRICAL. A **bridge** circuit is in a condition of balance when so adjusted that an e.m.f. in one branch produces no current in the conjugate branch. This is the case, for example, in a properly adjusted **Wheatstone bridge.**

BALANCE, JOLLY. A balance used for the determination of specific gravity of a substance by weighing it in air and in liquid. This balance consists of a spring from which the sample is suspended, with a scale for reading its position.

BALANCE, KEYBOARD. A balance in which all small weights (often up to 1 g) are handled by a series of keys mounted on the outside of the case. The weights are not handled manually, and their total can be determined by adding the weight-values of the keys depressed in a given weighing.

BALANCE, MECHANICAL. Mechanical balance consists of the equilibrium of masses, and can be divided into static and dynamic balance. Static balance occurs in a system when the **center of gravity** of the system coincides with its reactions. For example, a rotating body in static balance has its center of gravity coincident with its axis of rotation. A system may, however, be in static balance, but become unbalanced when the system rotates. Such a system, for example, as that shown in the accompanying figure may well



Case of Static Balance and Dynamic Unbalance

be in static balance, and satisfactorily pass a balance test which would consist of putting the shaft on absolutely horizontal parallel rails and trying the rotor for equilibrium in any position. But when this system rotates, the centrifugal forces of the two weights, not being in the same plane perpendicular to the axis of rotation, create a couple acting on the shaft. That couple rotates with the shaft and produces shaking forces at the journals, and vibrations in the foundation. The dynamic balancing of this system would involve the addition of a system of counter balances which, by themselves, would be in static equilibrium, but which in rotation would produce a couple equal in magnitude but opposite in direction to the one already considered.

BALANCE, MICRO. A **balance** for the precise weighing of small masses; the great sensitivity necessary is usually achieved by use

of the torsion of a quartz fiber as a means of determination of weight.

BALANCE, MOHR. A balance designed, like the Westphal balance, for determining densities of solids by weighing them in air and when suspended in a liquid of known density; if the density of the solid is known, that of the liquid may be determined.

BALANCE, RECIPROCATING. Reciprocating balance consists of opposing the shaking forces of a reciprocating mass by equal and opposite forces obtained from another reciprocating mass. One particularly difficult job of balancing occurs in a system consisting of both rotation and reciprocation, as exemplified by the piston, connecting rod, and crank mechanism. The difficulty lies in the fact that if perfect balance is secured in the direction of reciprocation by the employment of rotating counter balances, severe unbalance will result in a plane perpendicular to that direction The solution of this difficulty is a compromise in which only part of the reciprocating mass is counterbalanced, thus reducing the maximum degree of unbalance, but producing a smaller unbalance in two planes.

BALANCE, SPRING. A device for weighing in which the object to be weighed is suspended by a spring, calibrated so that a pointer attached to a point on the spring indicates weight directly by its position relative to a graduated scale. (Cf. **balance, Jolly.**)

BALANCE, STATIC. See **balance, mechanical.**

BALANCE, TORSION. A balance in which the weight is determined by the twisting force necessary to turn a wire or band. In many types, the force of torsion works in opposition to the force of gravity.

BALANCE, WESTPHAL. A **balance** designed for determining the densities of liquids or solids. It consists essentially of a plummet suspended from a beam, which is graduated and provided with riders. The densities of solids are determined by weighing them in air and in a liquid of known specific gravity; if the density of the solid is known, that of the liquid may be determined Commonly, the riders on this balance have weight-ratios of 1, 1/10, 1/100, 1/1000, and the beam has nine divisions calibrated so that the specific gravity of the liquid can be read directly.

BALANCED (PUSH-PULL) AMPLIFIER. See **amplifier, balanced (push-pull).**

BALANCED CURRENTS (ON A BALANCED LINE). Currents flowing in the two conductors of a **balanced line** which, at every point along the line, are equal in magnitude and opposite in direction.

BALANCED DETECTOR. See **detector, balanced.**

BALANCED LINE (TWO-CONDUCTOR). A **transmission line** consisting of two conductors in the presence of ground, capable of being operated in such a way that when the voltages of the two conductors at all transverse planes are equal in magnitude and opposite in polarity with respect to ground, the currents in the two conductors are equal in magnitude and opposite in direction. A balanced line may be operated under unbalanced conditions, and the aggregate then does not form a **balanced line system.**

BALANCED LINE SYSTEM. A system consisting of generator, **balanced line,** and load, adjusted so that the voltages of the two conductors at all transverse planes are equal in magnitude and opposite in polarity with respect to ground.

BALANCED MODULATOR. See **modulator, balanced.**

BALANCED OSCILLATOR. See **oscillator, balanced.**

BALANCED TERMINATION. For a system or network having two output terminals, a load presenting the same impedance to ground for each of the output terminals

BALANCED VOLTAGES (ON A BALANCED LINE). Voltages (relative to ground) on the two conductors of a **balanced line** which, at every point along the line, are equal in magnitude and opposite in polarity

BALANCER. (1) The circuit employed to balance out the **antenna effect** due to antenna-to-ground capacitance in **radio direction-finders.** (2) A machine consisting of two rotating devices, mechanically coupled, used to maintain or approximate balanced voltages on a three wire d-c line. When the load be-

tween one of the outer wires and ground is increased so as to decrease the voltage across this "leg," the half of the balancer connected across the leg acts as a generator, driven by the half of the machine across the other leg.

BALANCING, DETAILED. A principle of statistical mechanics which shows that the steady state of affairs at equilibrium is maintained by a direct balance between the instantaneous rates of opposing processes.

BALLAST TUBE. See **tube, ballast.**

BALLISTIC GALVANOMETER. See **galvanometer, ballistic.**

BALLISTIC MEASUREMENT. Any measurement in which an impulse is applied to the measuring device and the subsequent motion of the device is determined as a measure of the impulse. (See **ballistic pendulum** and **galvanometer, ballistic.**)

BALLISTIC PENDULUM. An instrument used for measuring the horizontal velocity component of a projectile. In its usual form it consists of a simple pendulum of mass M, and of natural frequency f. A projectile of mass m, moving with a velocity V strikes the bob and is imbedded in it. The maximum excursion X of the bob is then measured. Assuming that $M \gg m$ and that little damping is present, it may be shown by application of conservation laws that

$$V = \frac{2\pi f X M}{m}$$

BALLISTICS. The science which treats of the motion of masses projected into space, especially as associated with the motion of projectiles from guns and cannon. The complete path of a projectile is comprised of three separate and distinct phases. The first occurs in the bore of the gun, and the study of projectile motion here is that of interior ballistics. Secondly, there is the study of the path taken by the projectile as it flies through space from the gun to the target. This is exterior ballistics. Then, thirdly, there is the study of the penetration and the penetrating power of a projectile, which, for want of a better term, might be called penetration ballistics.

BALUN. The name balun (balanced to unbalanced) is applied in general to devices used for the transformation from an unbalanced (coaxial) **transmission line** or system to a balanced (two-wire) line or system, in which the two terminals have equal impedances to ground. Some change in impedance level may also be introduced between the balanced and unbalanced terminal-pairs of the device.

BALMER SERIES. A group of lines in the visible spectrum of atomic **hydrogen** represented by the formula:

$$\bar{\nu} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

in which $\bar{\nu}$ is the **wave number,** R_H is the **Rydberg number** for hydrogen (109,677 591 cm^{-1}) and n_1 is 2, while n_2 has various integral values.

BALY TUBE (CELL). A tube or cell of variable length used to hold solutions for absorption spectrographic determinations.

BAND (OR ENERGY BAND). See **band theory of solids; spectrum, band; frequency band.**

BAND, ALLOWED. A range of energies, which electrons may possess in a solid. (See **band theory of solids.**)

BAND, DEGRADING OF. See **band, shading of.**

BAND EDGE ENERGY. The energy of the edge of the **conduction band** or **valence band** in a solid; that is, the minimum energy required by an electron in order that it may be free to move in a **semiconductor** or the maximum energy it may have as a **valence electron.**

BAND-ELIMINATION FILTER. See **filter, band-elimination.**

BAND, FIRST OVERTONE. The spectral band produced when the vibrational energy of a molecule changes from an initial level in which the vibrational quantum number is 0 to a level in which the vibrational quantum number is 2, or the reverse.

BAND, FORBIDDEN. A range of energies which no electron in a solid may possess. (See **band theory of solids.**)

BAND, FUNDAMENTAL. The spectral band produced when the vibrational energy of a molecule changes from an initial level in which the vibrational quantum number is 0

to a level in which the vibrational quantum number is 1, or the reverse.

BAND HEAD. The wavelength of the sharpest edge of a spectral band. (See **spectrum, band.**)

BAND-IGNITOR TUBE. A **glow-discharge tube** in which conduction is initiated by the application of a high potential between the cathode and an external metal band.

BAND(S), INTERFERENCE GUARD. The two bands of frequencies additional to, and on either side of, the communication band and **frequency tolerance**, which may be provided in order to minimize the possibility of interference.

BAND-PASS FILTER. See **filter, band-pass.**

BAND PRESSURE LEVEL. The effective sound pressure level (see **sound pressure, effective**) for the sound energy contained within a specified frequency band of a given sound. Both the width of the band and the reference pressure should be stated.

BAND SCHEME. The **band theory of solids** requires the classification of the electronic states according to the energy bands to which they belong. There is a convenient theorem by which each band may be identified with a level of the independent atom, from which it arises as the atoms are brought together to make the solid. This identification, together with the spacing and width of the various bands, may be said to constitute the band scheme.

BAND, SECOND HARMONIC. Identical with **band, first overtone.**

BAND, SECOND OVERTONE. The spectral band produced when the vibrational energy of the molecule changes from an initial level in which the vibrational quantum number is 0 to a level in which the vibrational quantum number is 3, or the reverse.

BAND, SHADING OF. The gradual decrease in intensity of a spectral band (see **spectrum, band**) on the side opposite to the **band head.**

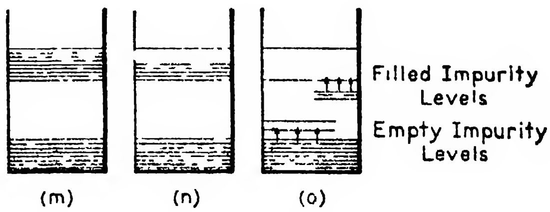
BAND, SIDE. A component in **carrier wave** transmission having a frequency equal to the sum or difference of the frequency of the carrier wave and that of the **modulating wave.**

BAND SPECTRUM. See **spectrum, band.**

BANDSPREAD. In the finer grade of radio **receivers,** such as used for communications purposes, it is desirable to be able to tune rapidly over a wide frequency range, yet be able to tune carefully to rather fine limits over a small range at any selected point in the wider range. This is accomplished by the band spreading tuning provided on such receivers. One method is to place a small capacitor gang in parallel with the main, tuning-capacitor gang.

BAND, SUMMATION. A combination **spectral band** for which the lower state is the vibrational ground state of the molecule.

BAND THEORY OF SOLIDS. The success of the simple **free electron theory of metals** was so striking that it was natural to ask how the same ideas could be applied to other types of solids, such as **semiconductors** and **insulators.** The basic assumption of the free electron theory is that the atoms may be stripped of their outer electrons, the resulting ions arranged in the crystalline lattice, and the electrons then poured into the space between. However, according to the **Pauli exclusion principle,** each electron must go into a distinct **state,** or **energy level.** It can be shown that the energy levels in the periodic lattice of ions fall into groups, or **bands;** in the **allowed bands** the levels are so closely spaced as to form effectively a continuum, but there are also **energy gaps,** or **forbidden bands,** i.e., certain ranges of energy in which there are no levels at all. Each allowed band contains just two levels for each atom in the crystal (corresponding to the two possible values of **spin**) but it is possible for various bands to overlap.



Band diagrams of *m*, insulator, *n*, metal, and *o*, semiconductor

The properties of the material depend on what happens when the levels are filled up, from the bottom, by the electrons. If the

number of electrons is such as to exactly fill certain bands, with a wide gap above them, the material will be an insulator (m). If the gap is very narrow, or if there are impurities present to create extra levels, the substance may be semiconducting (o). In these cases, it is difficult to supply sufficient thermal energy to an electron to promote it into the **conduction band** above the gap, where alone it is free to carry an electric current. In a **metal** (n), however, there is always a partially filled band, in which the electrons behave in many respects as if they were free. Direct evidence for the existence of bands is provided by the soft x-ray emission spectra, but the importance of the theory is not so much its correctness in detail as the simplicity of the **band scheme** by which the energy relations between various phenomena may be shown on a single diagram

BAND, THIRD HARMONIC. Identical with **band, second overtone.**

BAND, VALENCE. An allowed band of energies in a solid, identified with the ground states of the **valence electrons.** (See **band scheme** and **band theory of solids.**)

BANDWIDTH. The number of cycles per second expressing the difference between the limiting frequencies of a **frequency band.**

BANDWIDTH, EFFECTIVE. (1) For a specified **transmission system,** the bandwidth of an ideal system which (a) has uniform transmission in its **pass band** equal to the maximum transmission of the specified system, and (b) transmits the same power as the specified system when the two systems are receiving equal input signals having a uniform distribution of energy at all frequencies. This may be expressed mathematically as follows:

$$\text{Effective band width} = \int_0^\infty G\,df$$

where f is the frequency in cycles per second and G is the ratio of the power transmission at the frequency f, to the transmission at the frequency of maximum transmission.

(2) For a band-pass filter (see **filter, band-pass**) the width of an assumed rectangular band-pass filter having the same **transfer ratio** at a reference frequency, and passing the same mean-square value of a hypothetical current and voltage, having even distribution of energy over all frequencies.

BANDWIDTH OF ANTENNA. See **antenna, bandwidth of.**

BANDWIDTH OF A DEVICE. The range of frequencies within which performance, with respect to some characteristic, falls within specific limits.

BANDWIDTH OF A WAVE. The least frequency interval outside of which the **power spectrum** of a time-varying quantity is everywhere less than some specified fraction of its value at a reference frequency. This definition permits the spectrum to be less than the specified fraction with the interval. Unless otherwise stated, the reference frequency is that at which the spectrum has its maximum value.

BANTAM TUBE. An octal-based tube with a cylindrical glass envelope roughly the same diameter as the base. It is designated by the letters GT after the tube type-number, while its electrical equivalent in a larger envelope simply has the suffix G.

BAR. A unit of pressure in the metric system equal to one million dynes per square centimeter. It is slightly less than one atmosphere. Unfortunately, in acoustics the bar was once used to denote a pressure of one dyne per square centimeter. The commonly used unit today is the microbar, which is one dyne per square centimeter.

BAR GENERATOR. In television, the **generator** of pulses which are uniformly spaced in time, and are synchronized to produce a stationary bar pattern on a television screen.

BARDEEN AND BRATTAIN THEORY. The observation that a metal in contact with a **semiconductor** prefers to emit **"holes"** rather than electrons is explained by the tendency for electrons to remain bound in **surface states** near the junction.

BARIUM. Metallic element. Symbol Ba. Atomic number 56.

BARKHAUSEN CRITERION FOR OSCILLATORS. Sustained oscillations may be obtained in single-tube, feedback oscillators if the ratio of voltage fed back to the grid to the output voltage is equal or greater than

$$-\left(\frac{1}{\mu}+\frac{1}{g_m Z_l}\right)$$

where the negative sign signifies a 180° phase shift, μ and g_m are tube parameters, and Z_l is the effective load impedance seen by the tube.

BARKHAUSEN EFFECT. A series of minute "jumps" in the magnetization of iron or other ferromagnetic substance as the magnetizing force is continuously increased or decreased; discovered by H. Barkhausen in 1919. The effect may be observed by winding on the specimen, along with the magnetizing coil, a secondary coil connected to some sensitive detector of current fluctuations, such as an **oscillograph** or an audio amplifier. As the magnetizing current is steadily increased, the current in the secondary circuit, instead of being constant, exhibits a succession of small, sharp peaks or maxima, which the amplifier reveals by a faint clicking or snapping sound.

BARKHAUSEN-KURZ OSCILLATOR. See **oscillator, Barkhausen-Kurz.**

BARLOW RULE. The volumes of space occupied by the various **atoms** in a given **molecule** are approximately proportional to the **valencies** of the atoms; whenever an element exhibits more than one kind of valency the lowest value is generally selected.

BARN. A unit of nuclear **cross section** of the magnitude of 10^{-24} square centimeter per nucleus.

BARNETT EFFECT. In 1915, S. J. Barnett discovered that a relatively long iron cylinder, when rotated at high speed about its longitudinal axis, developed a slight magnetization, the value of which was proportional to the angular speed. He found the magnetization to be about 1.5×10^{-6} c.g.s. electromagnetic unit per revolution per sec for a cylinder about 7 cm in diameter and 50 cm long. The effect was attributed to the influence of the impressed rotation upon the revolving electronic systems within the atoms. An inverse effect was discovered about the same time by Einstein and de Haas; viz., an iron cylinder, suspended vertically, was observed to rotate slightly when suddenly magnetized.

BAROCLINIC. When isobaric surfaces and equal-density surfaces do not coincide the atmosphere is said to be baroclinic. If the surfaces do coincide, the atmosphere is said to be barotropic. Local winds often arise when the atmosphere is highly baroclinic.

BAROGRAPH. A recording **barometer.**

BAROMETER. An instrument for measuring the pressure of the atmosphere.

BAROMETER, ANEROID. A thin disk of metal covering the aperture of a box from which the air has been exhausted. Variation in atmospheric pressure causes a bulging of the disk, which shifts a pointer over a scale and so indicates the pressure.

BAROMETER, MERCURY. A column of mercury in an upright tube at least 80 cm long, from which the air has been exhausted; the upper end is sealed, and the lower dips into a cup containing mercury, which is open to the air. The height of the mercury column in the tube indicates the air pressure.

BAROMETRIC TENDENCY. The changes of barometric pressure within a specified time (usually 3 hours) before the observation, usually indicated by symbols at the right of the station as shown on the weather map.

BAROSCOPE. An indicating pressure gauge, consisting of a U-tube partly filled with liquid, having one end open to the atmosphere, and the other end connected to a system whose pressure is to be observed. Also called an open-end **manometer.**

BAROTROPIC FLUID. A fluid whose density is a single-valued function of the pressure, e.g., a compressible fluid whose specific entropy or temperature is everywhere the same. The **Kelvin circulation theorem** applies to barotropic fluids only.

BARRATT METHOD. An optical method of determining percent concentration of solutions throughout a very wide concentration range. A series of samples of known concentrations gives a curve with which the unknown is compared.

BARRETTER. A metallic resistor with a positive temperature coefficient of resistivity, used in control and measurement applications. The resistor may sometimes be enclosed in a gas-filled envelope to produce desired characteristics. (See **tube, ballast.**)

BARRIER. See **potential, nuclear.**

BARRIER (IN A SEMICONDUCTOR). (Obsolete.) See **depletion layer.**

BARRIER FILM RECTIFIER. A **junction rectifier.**

BARRIER LAYER. An electrical **double layer** formed at the surface of contact between a metal and a **semiconductor,** or between two metals, in order that the **Fermi levels** in each material should be the same. (See **junction.**)

BARRIER LAYER CELL. A photoelectric device which produces a small electromotive force upon the incidence of light or other radiant energy upon its barrier layer or **junction.**

BARRIER LAYER RECTIFIER. See **junction rectifier.**

BARRIER POTENTIAL. The potential difference across a **barrier layer.**

BARRIER REGION. See **barrier layer.**

BARTLETT FORCE. Phenomenologically postulated force between two **nucleons** derivable from a **potential** in which there appears an **operator** which exchanges the spins of the two particles but not their positions.

BARYE. The same as **bar.**

BASE. (1) One of the connections to a **transistor,** playing the role of the **cathode** in a vacuum tube. (2) Any substance which can replace the hydrogen of an acid, or which contains hydroxyl groups capable of uniting with the hydrogen of an acid to form water and a salt, or which contains trivalent nitrogen and can add directly to an acid to produce a salt in which the nitrogen is pentavalent

BASE ELECTRODE (OF A TRANSISTOR). An **ohmic contact** or **majority carrier contact** to the **base region.**

BASE-LOADED ANTENNA. An **antenna** (usually vertical) whose electrical height is increased by the addition of inductance in series with the antenna at the base.

BASE REGION. The interelectrode region of a transistor into which **minority carriers** are injected

BASE RESISTANCE TRANSISTOR. See **transistor parameter r_b.**

BASIC FREQUENCY. See **frequency, basic.**

BASILAR MEMBRANE. A flexible membrane separating two of the canals in the **cochlea** of the ear.

BASS. Frequencies at the lower end of the audible range.

BASS COMPENSATION. An **equalizer** used to correct the base response of an audio amplifier system.

BASS CONTROL. A **tone control** having the ability to increase or decrease the bass frequency gain of an audio amplifier.

BASS REFLEX. A **baffle** for **loudspeakers** which employs a tuned port or opening which returns the sound from the rear of the speaker in an additive phase. Thus, the sound output is enhanced over a certain range of frequencies

BATE EQUATION. A relationship of the form:

$$\log_{10}\left(\frac{\Lambda\eta}{\Lambda_0\eta_0}\right)^2 \frac{C}{1-\dfrac{\Lambda\eta}{\Lambda_0\eta_0}} = k + k'\left(\frac{C\Lambda\eta}{\Lambda_0\eta_0}\right)^h$$

$\dfrac{\eta}{\eta_0}$ = ratio of **viscosity** of a solution to that of water at the same temperature; $\dfrac{\Lambda\eta}{\eta_0}$ = corrected equivalent conductance; k, k', h, and Λ_0 are empirical constants; C is the concentration of the solution.

BATHOCHROME. A **chromophore** which lowers the frequency at which absorption occurs

BATHTUB CAPACITOR. A paper capacitor enclosed in a rounded-metal container resembling a bathtub.

BATSCHINSKI RELATION. The fluidity of a liquid is a linear function of the specific volume, i.e.,

$$\eta^{-1} = B(v - b)$$

where η is the viscosity, v is the specific volume, B is a constant, b is a characteristic volume, approximately equal to the volume, b, appearing in the **van der Waals equation.**

BATTERY. Any group of duplicate units which are contributing individually to a common effect.

By far the most common usage of the word is in reference to a collection of chemical cells for the production or storage of electrical energy. As such, the battery may be of the primary type, of which the individual unit is the primary **cell,** or it may be the ordinary **storage battery.**

BATTERY, PRIMARY. A group of primary cells. (See **cell, primary.**)

BATTERY, SECONDARY. A group of secondary cells. (see **cell, secondary**) as in a common storage battery.

BAUD. The unit of telegraph signaling speed, derived from the duration of the shortest signaling pulse. A telegraphic speed of one baud is one **pulse** per second. The term "unit pulse" is often used for the same meaning as the baud. A related term, the "dot cycle," refers to an on-off or mark-space cycle in which both mark and space intervals have the same length as the unit pulse.

BAUMÉ SCALE OF DENSITY. A convenient scale of density for use with floating hydrometers, whose depth of immersion is a linear function of the inverse of the density. The scale is linear in inverse density, that is, in specific volume.

BAY. (1) One segment of an **antenna array.** (2) A housing for transmitter equipment.

BAZOOKA. A form of **balun.**

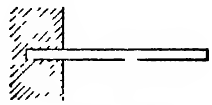
BC. (1) On tube-base diagrams, the letters indicating a base-shield connection. (2) Abbreviation for broadcast band.

BEAM. (1) A flow of electromagnetic radiation or of particles that is essentially unidirectional. (2) A straight or initially curved member which supports bearing loads without the aid of arch action (see specific types of beams which follow). (3) The term **beam** is also used to designate certain rolled-steel sections, such as the I-beam, which may be used either as beams, as defined in (2) above, or as **columns.**

BEAM BENDER. Colloquialism for **ion trap.** (See **kinescope.**)

BEAM CANDLE POWER. The equivalent beam candle power of a searchlight is defined as the **candle power** of a bare source which, if located at the same distance away, would produce at that point the same **illumination.**

BEAM, CANTILEVER. A beam which is rigidly connected at one end to a fixed support and free to move at the other end is called a cantilever beam. This theoretically



Cantilever Beam

fixed condition rarely occurs because of deformation of the supporting material. The maximum **bending moment** and maximum **shear** occur simultaneously at the face of the support. The usefulness of this type of beam is demonstrated in structures such as canopies, unbraced airplane wings and cantilever retaining walls.

BEAM, CONTINUOUS. A beam which has more than two supports. A beam which is continuous over several supports offers more difficulty in analysis than would a series of freely supported beams covering the same overall span. Because of the restraint at the intermediate supports, the continuous beam can carry a greater load than a simple beam of the same size and span. It is quite important to provide a firm foundation for the intermediate supports, as small deflections due to sinking of an intermediate support may introduce **stresses** of an entirely different nature and magnitude from those used in designing the beam.

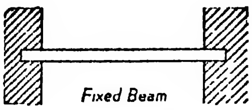
BEAM COUPLING. The production of an alternating current in a circuit connected between two electrodes through or by which a density-modulated electron beam is passed.

BEAM-COUPLING COEFFICIENT. The ratio of alternating driving current produced in a **resonator** to the alternating component of the initiating **beam current.** (See **beam coupling.**)

BEAM-DEFLECTION TUBE. See **tube, beam-deflection.**

BEAM, FIXED. A beam having the ends so firmly connected to the supports that the tangent to the **elastic curve** at the ends remains fixed in direction under varying load conditions. Theoretically, this requires the support to be absolutely unyielding. In

actual practice it is impossible to attain a perfectly rigid end support, and the design of a beam on the assumption of perfect re-



straint would be unduly optimistic. Therefore a design intermediate between perfect restraint and perfect freedom should be adopted for built-in beams, the departure from the conditions of perfect fixity being based upon the rigidity of the end supports. Since a fixed beam under load receives an end moment where it is built in, it will be stiffer than a freely supported beam. and thus have a smaller deflection under the same load.

BEAM, HOLDING. A diffuse beam of electrons for regenerating the charges retained on the dielectric surface of an electrostatic **memory** or **storage tube.**

BEAM LOADING. The production of an electronic admittance between two grids when an initially-unmodulated (constant-density) beam of electrons is shot across the gap between them.

BEAM PATTERN. See **directivity pattern.**

BEAM-POSITIONING MAGNETS. See **convergence magnets.**

BEAM-POWER TUBE. See **tube, beam-power.**

BEARING. (1) A member used to support, guide and restrain moving elements. The bearings of a machine "bear" the friction occasioned when the parts are in contact and have relative motion. Bearings are to be found in various forms, for example, rotating and sliding, weight-carrying and thrust-carrying, ball, roller, etc. (2) That part of a structure which transmits the load to the supports. Rolled steel plates, known as bedplates, are used for bearings for roof trusses, short plate girder bridges and wall bearing beams. Cast steel pedestals have been used in place of bedplates. Bridges are usually supported on hinged pedestals called shoes which are made of cast steel or from rolled steel shapes riveted or welded together. The hinge consists of a heat-treated steel pin through which the loads on the **truss** are transferred to the shoe. A fixed shoe is one which is firmly connected to the support. Shoes which allow a certain degree of movement in one direction are expansion shoes. In one type of expansion shoes rollers are used to provide the necessary means for movement and another type employs the principle of the rocker. Simply supported bridges require fixed shoes at one end and expansion shoes at the other end to take care of the movement due to temperature changes.

BEARINGS, TYPES OF. As defined under bearing (1), bearings are employed to support, guide and restrain moving elements. They may also be classified as friction bearings, which include journal bearings, ring-oiled bearings, and thrust bearings, and antifriction bearings, which include ball bearings and roller bearings. A journal bearing is composed of two essential parts, the journal, which is the inner cylindrical or conical part and which usually rotates, and the bearing or surrounding shell, which may be stationary as in the case of lineshaft bearings, or moving, as in a connecting rod bearing.

The simplest form of journal bearing embodies a shaft rotating in a hole in a frame or bracket. If any wear occurs in the bearing, it is necessary to replace the bracket or frame. For this reason, bearing holes are generally supplied with sleeves or bushings so that a comparatively inexpensive replacement is possible. The contact surfaces are lubricated through oil holes in the bushing.

Fig. 1 shows a split pillow block for transmission shafting, which has a babbitt-lined

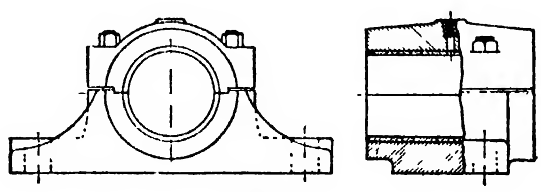


Fig. 1

bearing surface. The babbitt metal is cast into the cap and base of the bearing, and is locked in place by recesses or anchors in these members. This bearing is lubricated by a drop-feed oil cup or a grease cup which is screwed into the threaded hole in the cap. Split bearings are more expensive than solid or plain bearings but make it easier to remove

and replace the shaft. Pillow blocks are usually stocked by manufacturers in sizes to fit standard transmission shafting.

Fig. 2 shows a split *ring-oiled bearing* for overhead transmission shafting. The entire

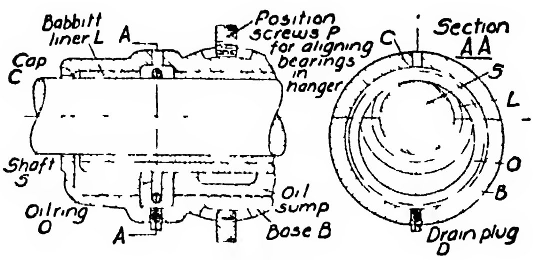


Fig 2

bearing is supported by two positioning screws *P* in the hanger of Fig 3 The hangers are made of cast iron or pressed steel and are attached to wooden ceiling joists by through bolts as illustrated, or by lag screws or hanger bolts Hangers may also be attached to steel ceiling girders by steel girder clamps and bolts

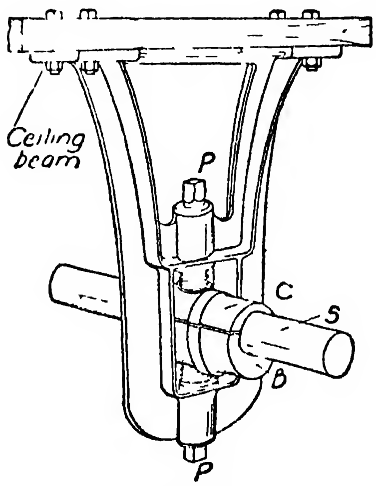


Fig 3

Thrust bearings are used for axial restraint, and are very important where heavy axial loads may prevail, as in vertical hydraulic turbo-generator sets, worm gearing, etc In such instances, a collar on the rotating shaft rests on a series of freely pivoting segments attached to the stationary bearing The rotation of the collar induces a wedge-shaped oil film between its lower surface and the top of the segments to provide thick-film lubrication. For light thrust loads, one or more thrust washers, restrained by separate collars or integral shoulders on the shaft, are satisfactory *Pivot bearings* are used in instruments and light mechanisms; the shaft or spindle has either a ball or spherical end or a 60° conical end, which rotates in a mating conical hole The resulting bearing carries both radial and thrust loads (See entry for **load.**)

Fig 4 illustrates several types of bearings for reciprocating slides Both dovetail and

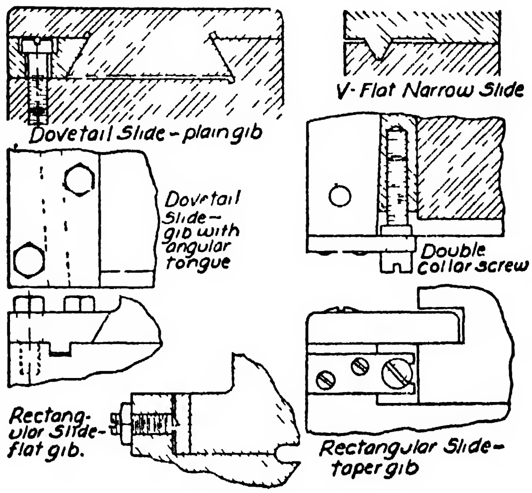


Fig 4

rectangular slides are generally made with some form of gib or adjustable strip so that the slide may be properly fitted and also to enable the slide to be clamped in the guide if desirable The taper gib, which is adjusted by a double collar screw, is by far the most effective gib but the guide must be planed with one tapered side The flat gib is the least expensive but does not give as good contact with the slide as the other forms The V-flat narrow slide is employed on lathes and in installations where the length of the slide is less than the total width of the member

Ball and roller bearings are known as *antifriction bearings*, and have certain advantages over journal bearings The actual bearing friction is less than in sliding bearings, and, as it is principally rolling friction, there is little danger of abrasion in machines that are frequently started and stopped under load Rolling bearings will maintain relatively accurate alignment of parts over long periods of time, can carry heavy momentary overloads without failure, and are very easily lubricated.

Fig. 5 illustrates a single-row radial ball bearing and housing. The bearing has four elements: the outer race which fits in the housing; the inner race which fits on the shaft; and the cage or retainer which separates the

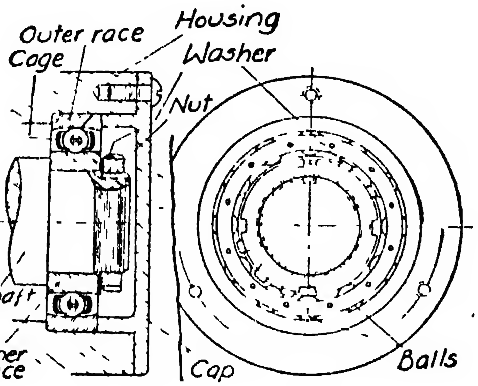


Fig 5

balls and keeps them properly spaced about the periphery of the unit Theoretically there is no reason why the balls could not roll on the shaft and in the housing, but the races are employed to maintain the proper fit and to provide satisfactory surfaces of the proper degree of hardness for the balls to roll on In the figure, the bearing is resting against a shoulder on the shaft, and is held in position by a lock nut which may be locked at any twenty-fourth of a turn by the washer

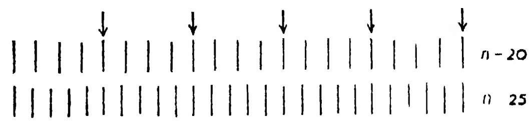
Ball bearings are generally supplied with bores, widths, and outer diameters in millimeters since the bearings were originally used in quantity in Germany, but bearings in standard inch sizes are also available at the present time. Radial ball bearings are made in three series- light, medium and heavy—and are numbered as follows: 205, 305 and 405, respectively. The bore, in millimeters, between sizes 204 and 213 in the light series, for example, is five times the last figure in the bearing number. Bearings 205, 305, and 405, for example, all have the same bore (25 mm) but the medium and heavy series bearings, which are used for greater loads than the 205 bearings, have larger outer diameters and greater widths.

Double-row bearings have approximately twice the load-carrying capacity of single-row bearings of the same bore, and occupy less space than two single-row bearings.

Angular-contact ball bearings are designed to take a combination of radial and thrust loads, and should be used in pairs unless the load is pure thrust. This type of bearing is adapted to preloading, which consists of placing it under an initial load which is independent of the working load. Preloading tends to reduce the axial deflection under working loads, thus maintaining accurate alignment of the shaft or spindle elements. Self-aligning bearings are double-row bearings with a spherical surface on the inside of the outer race. This construction allows some deflection in the shaft without causing the bearings to bind.

Roller bearings have a greater load-carrying capacity but develop more friction than ball bearings of similar size. Cylindrical roller bearings are made in three series, similar to ball bearings, and have rollers whose diameters are approximately equal to their lengths Needle bearings have cylindrical rollers of small diameter and considerable length, and operate without a cage or retainer They occupy very little diametral space in relation to their load-carrying capacity, and are therefore coming into extensive use in gear mountings, and as piston pin bearings in large internal combustion engines.

BEAT(S). A series of alternate maxima and minima in **vibration** amplitude, produced by the **interference** of two **wave** trains of different frequency. A familiar example arises in the case of musical **sounds.** If two musical pipes or strings of slightly different pitch are



Five coincidences in unit time between wave trains of frequencies 20 and 25

sounded together, the result is a more or less distinct throbbing, often disagreeable to the ear. The beat frequency is the difference of the two wave frequencies. Thus, if the two tones are middle-c (256) and c-sharp (271.2), there will be 15.2 beats per sec. If the two tones are **ultrasonic,** but have a frequency difference within the audible range, the beats themselves may produce an audible "beat tone." A similar effect results from the simultaneous reception of two radio wave trains which are nearly, but not quite, synchronized.

Thus if two stations are sending on carrier waves of 1000 and 998 kilocycles, the receiver will emit a shrill whistle of frequency 2000 cycles. This is the "heterodyne" effect, responsible for the annoying squeals and tremolos often heard in radio reception. The effect is utilized in heterodyne code receivers and in the **frequency-conversion** section of the modern radio. One type of radio **"fading"** may be regarded as a beat phenomenon of long period.

BEAT FREQUENCY. When two signals of different frequencies are applied to a non-linear circuit, they will combine, or beat together, and give, among other components, one which has a frequency equal to the difference of the two applied frequencies. This difference frequency is known as the beat frequency.

BEAT-FREQUENCY COMPONENT. The sum and/or difference frequencies produced as a result of **heterodyning.** (See **beat note.**)

BEAT-FREQUENCY OSCILLATOR. (1) Any conventional **oscillator** whose function is to produce the signal to mix with a signal whose frequency is to be shifted. Thus in a **continuous wave** receiver, it is the oscillator causing an audible beat, in the **superheterodyne** it is the oscillator causing the intermediate frequency beat. (See **beat frequency.**) (2) An **audio frequency** oscillator containing two **radio frequency** oscillators, and supplying their **beat frequency** as its output.

BEAT NOTE. The wave of difference frequency created when two sinusoidal waves of different frequencies are supplied to a non-linear device.

BEATING. A phenomenon in which two or more periodic quantities of different frequencies produce a resultant having pulsations of **amplitude.**

BEATTIE AND BRIDGEMAN EQUATION. A form of the **equation of state,** relating the pressure, volume, and temperature of a gas, and the **gas constant.** The Beattie and Bridgeman Equation applies a correction for reduction of the effective number of molecules by molecular aggregation, due to various causes. It has been stated in more than one form, an example of which is:

$$P = \frac{RT(1 - \epsilon)}{V^2}(V + B) - \frac{A}{V^2}$$

in which P is the pressure, T is the absolute temperature, V is the volume, R is the gas constant and A, B and ϵ are quantities defined in terms of five empirical constants, A_0, B_0, a, b, and c by the following relationships:

$$A = A_0\left(1 - \frac{a}{V}\right)$$

$$B = B_0\left(1 - \frac{b}{V}\right)$$

$$\epsilon = \frac{c}{VT^3}$$

BEAUFORT WIND SCALE. In the days of sailing vessels, Admiral Beaufort introduced a wind scale for judging wind force on the sails of a vessel. Beaufort numbers have since then been correlated to a range of wind velocities, and the scale has continued in universal use for describing wind velocity.

Code Number	Wind Velocity (m.p.h.)	Description
0	0–1	Calm
1	1–3	Light air
2	4–7	Light breeze
3	8–12	Gentle breeze
4	13–18	Moderate breeze
5	19–24	Fresh breeze
6	25–31	Strong breeze
7	32–38	Moderate gale
8	39–46	Fresh gale
9	47–54	Strong gale
10	55–63	Whole gale
11	64–75	Storm
12	Over 75	Hurricane

BECKMANN METHOD. See **boiling point, methods of determining elevation of,** and **freezing point, methods of determining depression of.**

BECQUEREL RAYS. Radiation emitted by radioactive substances, discovered in early work on radioactivity by the action upon photographic plates. These rays were later named **γ-rays.**

BEER LAW (1852). If two solutions of the same salt be made in the same solvent, one of which is, for example, twice the concentration of the other, the absorption due to a given thickness of the first solution should be equal

to that of twice the thickness of the second. Sometimes written

$$I = I_0 e^{-\alpha c x}$$

where I is the intensity of light transmitted, I_0 is the intensity of the incident light, e is the natural logarithmic base, c is the concentration of the solution in moles per liter, x is the thickness of the transmitting layer, and α is the molar absorption coefficient.

In general Beer's law is used for light of a particular narrow wavelength band and then α is the specular molar absorption coefficient.

The Beer law is also written

$$I = I_0 10^{\epsilon c x}$$

where ϵ is known as the molar extinction coefficient. Not all solutions obey the Beer law. (See also the **Bouguer law.**)

BEL. A dimensionless unit for expressing the ratio of two values of power, the number of bels being the logarithm to the base 10 of the power ratio. With P_1 and P_2 designating two amounts of power and N the number of bels corresponding to the ratio P_1/P_2,

$$N = \log_{10}(P_1/P_2)$$

BÉNARD CONVECTION CELLS. When a layer of liquid is heated from below, the onset of **convection** is marked by the appearance of a regular array of hexagonal cells, the liquid rising in the center and falling near the wall of each cell. The criterion for the appearance of the cells is that the **Rayleigh number** should exceed 1700 (for rigid boundaries).

BENCH PHOTOMETERS. Instruments for comparing the luminous intensities of two sources (see **photometry**) by finding a point so located between the two light-sources under comparison that the flux densities produced by them at that point are equal. The luminous intensities of the two sources are then proportional to the squares of their distances from that point. To this end, the two sources are mounted near the extremities of the scale of an **optical bench,** and on a movable carriage between them is some device, called the photometer "head," for receiving and comparing the illuminations from opposite directions.

BEND (E-TYPE). A bend in a **waveguide mode** in the plane of the electric field.

BEND (H-TYPE). A bend in a **waveguide mode** in the plane of the magnetic field.

BENDING MOMENT. The external bending moment at any section in a beam is equal to the algebraic sum of the moments, about the gravity axis of the section. This definition assumes that all of the external forces are coplanar, that is, act in one plane. An internal resisting moment at any section is equal to the sum of the moments of the internal **stresses** about the gravity axis of the section. The external bending moment acting on any section is numerically equal to the internal resisting moment but acts in the opposite direction. External moments are positive or negative depending upon the direction in which they tend to rotate the section of the beam under consideration. (Cf. **moment.**)

BENDING OF LIGHT. Consequence of general relativity theory (see **relativity theory, general**), coupled with the identification of a **null-geodesic** as a possible path of a light ray, that a light path is curved on passing near a massive object. For the sun, the theoretical value is 1.75 seconds, in much better agreement with observation ($\sim 2''$) than the value .875 seconds derived from the Newtonian theory of gravitation.

BENDING, UNSYMMETRICAL. The condition which exists at any cross-section of a flexural member (see **flexure**) when the plane of the **loads** contains the **shear center** but does not coincide with either of the two **principal planes of bending** is known as unsymmetrical bending. Under these conditions the **flexure** formula is not applicable because the **neutral axis** is not perpendicular to the plane of the loads although it does pass through the **center of gravity** of the cross-section.

BENHAM TOP. A disc bearing characteristic black and white portions, which under certain conditions of angular velocity and **illuminance,** induces chromatic responses. (See **Fechner's colors.**)

BERKELEY AND HARTLEY METHOD. The measurement of **osmotic pressure** by the application of a gradually increasing external pressure to the solution until the entry of solvent into the solution through the semipermeable membrane is just prevented.

BERNOULLI EQUATION. A first order non-linear **differential equation**

$$\frac{dy}{dx} + f(x)y = g(x)y^n.$$

It may be made **linear** by the substitution $y = u^{1/n-1}$, giving

$$\frac{du}{dx} + (1 - n)f(x)u = (1 - n)g(x).$$

BERNOULLI LAW (OR THEOREM). A statement of the law of the conservation of energy for steady flow of an inviscid fluid. If the fluid may be regarded as incompressible, the sum, $p + \frac{1}{2}\rho v^2 + \rho gh$ (where p is local hydrostatic pressure, $\frac{1}{2}\rho v^2$ is the kinetic pressure, and gh is the local gravitational potential), is constant along any one streamline. If the flow is also irrotational, the sum is constant over the whole flow. The law may be generalized for compressible flow.

BERNOULLI NUMBER. A coefficient in the power series

$$\frac{x}{e^x - 1} = \sum_{n=0}^{\infty} \frac{B_n x^n}{n!}.$$

The first few numbers are $B_0 = 1$; $B_1 = -\frac{1}{2}$; $B_3 = B_5 = B_7 = \cdots = 0$; $B_2 = \frac{1}{6}$; $B_4 = -\frac{1}{30}$; $B_6 = \frac{1}{42}$; $B_8 = -\frac{1}{30}$; $B_{10} = \frac{5}{66}$. They occur in the **Euler-Maclaurin formula.** Variations in definition and notation are often found.

BERNOULLI POLYNOMIAL. A coefficient in the power series

$$\frac{t(e^{xt} - 1)}{(e^t - 1)} = \sum_{n=0}^{\infty} \frac{\phi_n(x)}{n!} t^n.$$

The first few polynomials are $\phi_2 = x(x - 1)$; $\phi_3 = x(x^2 - \frac{3}{2}x + \frac{1}{2})$; $\phi_4 = x^2(x^2 - 2x + 1)$; $\phi_5 = x(x^4 - \frac{5}{2}x^3 + \frac{5}{3}x^2 - \frac{1}{6})$. Variations in their definition and the notation often occur.

If the nth polynomial is expanded in a **Maclaurin series,** the coefficients are related to the **Bernoulli numbers.**

BERTHELOT CONDENSATION METHOD FOR LATENT HEAT OF VAPORIZATION. A given amount of vapor is condensed in a vessel inside a water bath. The weight of the condensed vapor and the rise in temperature of the water bath are measured.

BERTHELOT EQUATION. A form of the **equation of state,** relating the pressure, volume, and temperature of a gas, and the gas constant R. The Berthelot equation is derived from the **Clausius equation** and is of the form

$$PV = RT\left[1 + \frac{9PT_c}{128P_cT}\left(1 - 6\frac{T_c^2}{T^2}\right)\right]$$

in which P is the pressure, V is the volume, T is the absolute temperature, R is the gas constant, T_c is the critical temperature, and P_c the critical pressure.

BERYLLIUM. Metallic element. Symbol Be. Atomic number 4.

BESSEL DIFFERENTIAL EQUATION. A second order equation with a **regular singular point** at $x = 0$ and an **irregular** one at $x = \infty$

$$x^2y'' + xy' + (x^2 - n^2)y = 0$$

where n is a constant. Its solutions, called **cylindrical functions,** are **Bessel, Hankel,** and **Neumann functions.**

BESSEL FORMULA FOR INTERPOLATION. A **central difference equation** (see also **difference, finite**)

$$y_{v+\frac{1}{2}} = \mu y_{\frac{1}{2}} + \delta y_{\frac{1}{2}} v + \mu\delta^2 y_{\frac{1}{2}} \frac{(v^2 - \frac{1}{4})}{2!} + \delta^3 y_{\frac{1}{2}} \frac{v(v^2 - \frac{1}{4})}{3!} + \mu\delta^4 y_{\frac{1}{2}} \frac{(v^2 - \frac{1}{4})(v^2 - \frac{9}{4})}{4!} + \cdots$$

The independent variable x is equally spaced so that $(x_n - x_0) = nh$ and the desired value of y corresponds to $x = x_0 + hu$; $v = u - \frac{1}{2}$. The other symbols are defined as follows: $\delta^m y_{\frac{1}{2}} = \Delta^m{}_{(1-m)/2}$; $\mu y_{\frac{1}{2}} = (y_0 + y_1)/2$; $\mu\delta^m y_{\frac{1}{2}} = (\delta^m y_0 + \delta^m y_1)/2$.

BESSEL FUNCTION. A solution of the **Bessel differential equation.** There are three kinds of Bessel functions but those of the second kind are also called **Neumann functions** and those of the third kind, **Hankel functions.** The Bessel function of the first kind may be defined by a **generating function** and by the infinite series

$$J_n(x) = \left(\frac{x}{2}\right)^n \sum_{k=0}^{\infty} \frac{(ix/2)^{2k}}{k!\Gamma(n + k + 1)}.$$

Provided n is not zero or an integer, the general solution of the differential equation is $y = AJ_n(x) + BJ_{-n}(x)$, where A, B are constants of integration. In the integral case, $J_n = J_{-n}$ and the second linearly independent solution is a **Neumann function.**

The Bessel functions of half-integral order, $n = m + \frac{1}{2}$; $m = 0, \pm 1, \pm 2, \cdots$ are linear combinations of sin x and cos x.

BESSEL INEQUALITY. If a function $f(x)$ is expressible in terms of an **orthonormal** set of functions ϕ_i using expansion coefficients $c_i = \int f\phi_i dx$, then the Bessel inequality states

$$\sum_{i=1}^{\infty} c_i^2 \leq \int f^2 dx.$$

If $f(x)$ is **integrable square,** the sum of the square of the expansion coefficients is thus convergent.

When the equality holds, the result is known as the Parseval theorem.

Both relations may also be written in vector form.

BETA. (1) Coefficient of volume expansion (β). (2) Plane angle (β). (3) Relativity ratio (β). (4) See also **beta-particle** and **beta-ray.** (5) Ratio of speed to speed of light (β). (6) The short-circuit current gain in a grounded-emitter, transistor amplifier ($\beta = \alpha/(1 - \alpha)$, where α is the current amplification).

BETA-ABSORPTION GAUGE. An instrument which measures the thickness or density of a sample by measuring the absorption of **β-rays** in the sample.

BETA DECAY. See **beta disintegration.**

BETA-DECAY, DOUBLE. See **double beta-decay.**

BETA DISINTEGRATION. A radioactive transformation of a nuclide wherein the **atomic number** is changed by +1 or −1, and the **mass number** is unchanged. When the atomic number is increased by 1, negative β-particle emission occurs, and when the atomic number is decreased by 1, there is positive β-particle **(positron)** emission or **electron capture.**

BETA DISINTEGRATION ENERGY. (1) The disintegration energy of a beta-decay process; symbol Q_β. For negatron emission it is equal to the sum of the kinetic energies of the **β-particle,** the **neutrino,** and the recoil atom (usually negligible), and is obtained experimentally from the maximum energy of the **β-particle spectrum.** For positron emission, the energy equivalence of two **electron rest-masses** must be added to the aforementioned sum, since the products include the positron and one negative electron in addition to the neutral product atom, the energy equivalent to their masses ultimately appears as radiant energy of **annihilation radiation.** For **electron capture,** the disintegration energy is equal to the sum of the kinetic energy of the neutrino and the electronic excitation energy of the product atom (usually, the binding energy, in the neutral product atom, of an electron equivalent to that which was captured).

(2) Often, implicitly, the ground-state β-disintegration energy, which is the total energy released in a β-transition between isobars in their ground states; symbol Q_{β_0}. It includes the energies of any γ-radiation and associated radiations following the β-process itself.

BETA-EMITTER. A radionuclide that undergoes disintegration by emission of a **β-particle.**

BETA FUNCTION. An improper integral

$$B(m,n) = \int_0^1 x^{m-1}(1 - x)^{n-1}dx; \quad m > 0, n > 0$$

and also called an **Eulerian integral** of the first kind. It can be expressed in terms of the **gamma function** by the equation

$$B(m,n) = \frac{\Gamma(m)\Gamma(n)}{\Gamma(m + n)}.$$

BETA PARTICLE. A negative electron or positive electron (positron) emitted from a nucleus undergoing β-disintegration.

BETA RAY. A stream of **β-particles.**

BETA-RAY SPECTRUM. (1) The distribution in energy or momentum of the β-particles (not including conversion electrons) emitted in a β-decay process. The β-ray spectrum is always continuous up to a maximum energy. Its shape depends upon the nature of the particular β-decay process.

(2) Sometimes, and loosely, the energy spectrum of the electrons emitted by a radio-

active source, irrespective of their origin. In addition to the continuous spectrum of definition (1), it may show lines due to **internal conversion** or to Auger electrons. (See **Auger effect.**)

BETATOPIC. Differing by, or pertaining to a difference by, unit atomic number. Thus, if one atom or element can be considered to form another atom or element, by ejection of an electron (beta-particle) from its nucleus (and thus increasing its nuclear charge by +1), the two atoms are betatopic.

BETATRON. The betatron, invented in 1941 by D. W. Kerst at the University of Illinois, is an electron **accelerator** capable of producing electron beams of high energy as well as x-rays of extremely high penetrating power. This device differs from the cyclotron in at least two fundamental respects: first, the electrons are accelerated by a rapidly-changing magnetic field, and second the circular orbit of the particles has a constant radius.

During World War II a 350-ton betatron was constructed by the General Electric Company and put into use as a source of extremely penetrating x-rays. In this instrument electrons accelerated to 100 mev energy, and impinging upon a target, give rise to x-rays capable of penetrating many feet of solid iron and lead.

BETHE-HOLE DIRECTIONAL COUPLER. See **coupler, Bethe-hole directional.**

BETHE-SALPETER EQUATION. Equation in **quantized field theory** describing the bound state of two interacting particles, formulated in a completely relativistic manner and employing a relative time variable.

BEV. Abbreviation for billion **electron-volts,** a unit of energy.

BEVATRON. A six billion electron volt accelerator of protons and other atomic particles, located at the University of California, Berkeley. The protons are first accelerated by a Cockcroft-Walton transformer cascade accelerator to 500,000 electron-volts. After deflection by a magnetic field, they are speeded up to 10 million electron-volts by a linear accelerator. At this speed they are inflected into the main unit, which consists of 4 quadrant segments spaced so that the particle orbits are quarter-circles connected by 20-foot straight sections. This forms a "race track" 385 feet long, in the field of a 10,000 ton magnet, actuated by a motor-generator with a large flywheel, from which a peak power of 100,000 kw is drawn. The protons attain a speed equivalent to 6 billion electron volts.

BEZOLD-BRÜCKE EFFECT. A shift in **hue** which is the result of a variation in **luminance.** The Bezold-Brücke effect may be represented by **chromaticity loci,** of specified **luminance,** with **hue** and **saturation** constant, when **luminance,** and consequently **brightness,** are varied. It is a relationship, of psychophysical nature, between psychophysical specifications and color sensation attributes.

BFO. Abbreviation for **beat-frequency oscillator.**

BIANCHI IDENTITIES. The relations

$$B^{\epsilon}{}_{\mu\nu\sigma,\tau} + B^{\epsilon}{}_{\mu\sigma\tau,\nu} + B^{\epsilon}{}_{\mu\tau\nu,\sigma} = 0$$

between the covariant derivatives of the **Reimann-Christoffel tensor.**

BIAS. In electrical work, a voltage whose principal function is to locate the operating point on the characteristic of a piece of apparatus. The term is most commonly applied to the grid voltage of a vacuum **tube,** in which case it means the d-c voltage (other than signal voltage) applied between the **cathode** and control **grid** of the tube. In this connection the term C-bias is also commonly used. The bias may be obtained from a source of d-c voltage, from the potential drop across a resistor (cathode resistor) in the cathode circuit or, when the grid carries current, from the drop across a resistor in the grid circuit. The first method is called fixed bias and the latter two self-bias. Bias is also used in **telegraphy** to indicate undesirable voltage additions to or subtractions from the code signals.

BIAS CELL. A small electric cell which is capable of supplying an open-circuit voltage of 1½ or 1¾ volts indefinitely.

BIAS LIGHTING. A method of increasing **iconoscope** sensitivity by illuminating the **mosaic** from the rear with a constant light-source.

BIAS TELEGRAPH DISTORTION. See **distortion, bias telegraph.**

BIAS WINDINGS. Of a saturable reactor are those control windings by means of which the operating condition is translated by an arbitrary amount.

BIAXIAL CRYSTAL. A birefringent crystal with two axes along which there is no **double refraction.**

BICONICAL ANTENNA. See **antenna biconical.**

BIDIRECTIONAL MICROPHONE. See **microphone, bidirectional.**

BIDIRECTIONAL PULSE. See **pulse, bidirectional.**

BIDIRECTIONAL PULSE TRAIN. See **pulse train, bidirectional.**

BIFILAR REFLECTOR. See **reflector, bifilar.**

BILATERAL TRANSDUCER. See **transducer, bilateral.**

BILINEAR CONCOMITANT. See **adjoint equation.**

BILINEAR FORM. See **form, bilinear.**

BILLET SPLIT LENS. A lens is cut into two halves by a cut parallel to the **optical axis.** By displacing the axes of the two halves slightly, overlapping beams from a **slit** source will form **interference fringes.**

BIMORPH (BIMORPH CELL). Two piezoelectric plates cemented together in such a way that the application of a potential to them causes one to expand and the other to contract, thus producing a bending of the combination.

BINAC. One type of high-speed, electronic, digital computer.

BINARY CELL. In computer work, an information-storing element which can have one or the other of two stable states.

BINARY-CODED DECIMAL SYSTEM. A system of number representation in which the decimal digits of a number are expressed by binary numbers.

BINARY NUMBER SYSTEM. A number system which uses two symbols (usually denoted by "0" and "1") and has two as its base, just , the decimal system uses ten symbols ("0, 1, $\cdots$, 9") and the base ten. (See also **positional notation** and **radix.**)

BINARY POINT. The **radix** point in the binary system.

BINAURAL INTENSITY EFFECT. If θ is the angle made with the median plane of the line joining the ears by a line drawn in the apparent direction of a sound source, and if sound of the same frequency and same phase is incident on both ears, then

$$\theta = K \ln \frac{I_L}{I_R},$$

where I_L is the intensity measured at the left ear, and I_R is the intensity measured at the right ear. K is a frequency-dependent constant.

BINAURAL PHASE EFFECT. If the sound intensity at the ears is maintained alike and differences in phase are introduced, there is an angular displacement θ of the apparent sound source from the median plane. The relation between this angle and the phase difference ϕ is given by

$$\theta = K\phi,$$

where K depends upon frequency.

BINAXIAL CRYSTAL. See **biaxial crystal.**

BINDING ENERGY. (1) The energy required to remove a particle or other entity from a system. (See specific entries which follow.) (2) The energy required to disperse a solid into its constituent atoms, against the forces of cohesion. In the case of ionic crystals, it is given by the **Born-Mayer equation.**

BINDING ENERGY, ALPHA-PARTICLE. The energy required to remove an **α-particle** from a nucleus. For spontaneous α-emitters, it is the negative of the ground state **α-disintegration energy.** For most light nuclides the α-particle binding energy is positive and is equal to several mev. For nuclides of mass number $\sim$125, it is approximately zero. For nuclides of mass number $\sim$150 to 200, it is negative by $\sim$1 to 3 mev, but the lifetimes for α-disintegration are generally too long for detection of α-activity. For most nuclides of mass number exceeding 200, the α-particle binding energy is negative by $\sim$4 to 8 mev, leading to observable α-activity.

BINDING ENERGY, ELECTRON. The energy necessary to remove an electron from an atom. It is identical with the **ionization potential.**

BINDING ENERGY, ELECTRON, TOTAL. The energy necessary to remove all the electrons from an atom to infinite distances, so that only the nucleus remains. It is equal to the sum of the successive **ionization potentials** of that atom.

BINDING ENERGY, NEUTRON. The energy required to remove a single neutron from a nucleus. Most known neutron binding energies are in the range 5-8 mev, though that for H^2 is 2.23 mev, that for Be^9 is 1.67 mev, and that for C^{12} is 18.7 mev.

BINDING ENERGY, NUCLEAR. The energy that would be necessary to separate an atom of atomic number Z and mass number A into Z hydrogen atoms and A-Z neutrons. This energy is the energy equivalent of the difference between the sum of the masses of the product hydrogen atoms and neutrons, and the mass of the atom, it includes the effect of electronic binding. (See **binding energy, electron, total.**)

BINDING ENERGY, PROTON. The energy necessary to remove a single proton from a nucleus. Most known proton binding energies are in the range 5-12 mev, although that for H^2 is 2.23 mev, that for He^4 is 19.8 mev, and those for Li^5 and Be^9 are negligible.

BINGHAM EQUATION. A relationship which gives the **fluidity** (reciprocal viscosity) of mixtures of solutions of non-electrolytes:

$$\phi = x_A\phi_A + x_B\phi_B$$

where ϕ is the fluidity of the mixture, ϕ_A and ϕ_B the fluidities of the components, and x_A and x_B are the volume fractions of the components. The deviations from this relationship are due to volume changes on mixing.

BINOCULAR. An instrument composed of two similar **telescopes,** one for each eye, usually with focusing tubes controlled by a common screw adjustment.

BINOCULAR, PRISM. A **binocular** having a pair of right-angled, total-reflection prisms in each telescope. This arrangement shortens the tube length, as compared with an ordinary field glass of equal power, and since it also permits the objectives to be set further apart than the eyepiece, it increases the "stereo power" of the instrument as a binocular. (See **binocular vision.**)

BINOCULAR VISION. The possession of two eyes set at a distance apart, but with approximately parallel axes, enables us to obtain two views from slightly different angles, and thus to become sensible of the solidity of single objects and to get an idea of the actual distribution of different objects in space. In some manner the brain is able, through long experience, to blend the two different sensory pictures from the two different retinal images and to interpret the resulting sensation in terms of geometrical solidity. There is, however, a limit to the distance at which this impression is perceptible, and for very distant objects other factors must be relied upon, such as the apparent size (as of buildings or trees), or the opacity of the atmosphere (as in viewing distant mountains). In the absence of such factors, no estimate of distance can be formed; thus the stars all appear to be at the same distance. This limiting "stereoscopic radius" is for normal, unaided eyes, only a few hundred feet, but with a **binocular** telescope, and especially with a prism binocular (see **binocular, prism**), it is increased in a ratio called the "stereo power" of the instrument.

BINOMIAL. A **polynomial** containing two terms.

BINOMIAL COEFFICIENT. The coefficient of the variable in a **binomial series.** The $(k+1)$th coefficient of order n is $\dfrac{n!}{k!(n-k)!}$, usually designated by the symbol $\dbinom{n}{k}$. It equals the number of **combinations** of n things taken k at a time. Properties of the coefficients include

$$\binom{n}{0} = \binom{n}{n} = 1; \quad \binom{n}{k} + \binom{n}{k+1} = \binom{n+1}{k+1};$$

$$\binom{n}{n-k} = \binom{n}{k}.$$

BINOMIAL THEOREM. A rule for expanding $(x+y)^n$, where n is a positive integer. The result is

$$(x + y)^n = x^n + nx^{n-1}y + \frac{n(n-1)}{2!}x^{n-2}y^2 + \cdots + y^n$$

The $(k + 1)$th term is

$$\binom{n}{k} x^{n-k}y^k$$

where $\binom{n}{k}$ is the **binomial coefficient.**

BIOLOGICAL SHIELD. A shield used to reduce the intensity of radiation transmitted to an amount permissible physiologically.

BIOLUMINESCENCE. See discussion under **luminescence.**

BIOPHYSICS. The physics of biological processes or phenomena. So much has been learned in recent years as to the mechanisms of life functions that biophysics has taken its place along with biochemistry as an important area of material science.

Of course such matters as the dynamics of animal skeletons—with bones as levers or toggle joints—have always been cited in physics. Also the eye has long been recognized as an optical, the ear as an acoustic, instrument. More recent is the identification of nerve responses with electric currents. An extensive phase of biophysics is the role of osmosis in vital processes such as secretion and respiration.

Among the puzzling problems of biophysics are the phenomena of "bioluminescence," that is, the emission of light by living organisms such as the firefly and luminous fungi; and animal electricity, exhibited by such creatures as the electric eel.

The uses of physical techniques in medical practice are closely related to this field; such for example as the applications of x-rays and radioactivity to diagnosis and treatment, and the various phases of electrotherapy and diathermy.

BIOT-SAVART LAW. A law expressing the intensity of the **magnetic field** in the neighborhood of a long, straight wire carrying a steady **current.** If a permanent **magnet** is rigidly attached in any position to a rod or frame which is capable of rotation about such a wire as an axis, it is found that there is no resultant **torque** about the wire. From this it is readily shown that the field intensity varies inversely as the distance from the wire (see **vector potential**). If the current is i (abamperes) and the distance r (cm), the intensity is given by the Biot-Savart law as $H = 2i/r$ (oersteds). The **Ampere law** is sometimes called by this name, since either of the two laws may be deduced from the other.

BIPOLAR COORDINATE. A curvilinear coordinate system. Choose two points $\pm a$ on the X-axis of a rectangular coordinate system. Then any point (x,y) in the XY-plane could be measured in either of two **polar coordinate** systems where the poles are at $x = \pm a$; the polar axis in both systems is the X-axis; the two polar angles are θ_1, θ_2; the two radius vectors are r_1, r_2. Define the parameters $\xi = \theta_1 - \theta_2$; $\eta = \ln r_2/r_1$ and, in terms of these parameters,

$$x = \frac{a \sinh \eta}{\cosh \eta - \cos \xi}; \quad y = \frac{a \sin \xi}{\cosh \eta - \cos \xi}$$

which are families of circles along the X- and Y-axes, respectively. Translation of these circles along the Z-axis produces the bipolar coordinates which are families of right circular cylindrical surfaces with axes parallel to the Z-axis and centers at $y = 0$, $x = 0$, respectively $(\xi,\eta = \text{constant})$, where

$$0 \leq \xi \leq 2\pi; \quad -\infty \leq \eta \leq \infty.$$

The third surface is a plane perpendicular to the Z-axis ($z =$ constant).

BIPRISM. See **Young's Interference Experiment.**

BIQUADRATIC. See **equation, quartic.**

BI-QUARTZ. By placing two adjoining pieces of equal thickness of quartz, one dextro-, the other laevo-rotatory, over the **analyzer** in a **polariscope,** the accuracy of setting can be increased. Such a double block is called a bi-quartz.

BIREFRINGENCE. **Double refraction** or the splitting of a ray of incident light into two components which travel at different velocities. (See **ordinary ray,** and **extraordinary ray.**)

BISMUTH. Metallic element. Symbol Bi. Atomic number 83.

BISTABLE. A circuit with two stable states. See **scale-of-two, Eccles-Jordan circuit, trigger circuit,** and **multivibrator, bistable.**

BJERRUM DOUBLE BAND. When the absorption spectra in the near infrared of many gaseous substances (e.g., HCl, HBr, HI and CO, but not O_2, N_2, and H_2) is observed with a thin layer of gas and small dispersion, only a single absorption "line" (also called fundamental band) is observed in the whole region. However, with greater resolution, this "line" is found to consist of two maxima close together, called the Bjerrum double band.

BJERRUM THEORY. In the case of a monatomic gas, no energy is possessed other than that due to translational movement. As regards the rotation of the molecule as a whole, the potential energy of rotation is negligible compared with the kinetic energy. In regard to atomic vibrations the total vibrational energy is θRT where θ is a function of the temperature T and of the vibration frequency v.

BLACK BODY. This term denotes an ideal body which would, if it existed, absorb all and reflect none of the **radiation** falling upon it; its reflectivity would be zero and its absorptivity would be 100%. The chief interest attached to such a body lies in the character of the radiation emitted by it when heated and the laws which govern the relations of the **flux** density and the **spectral energy distribution** of that radiation to the temperature.

The total emission of radiant energy from a black body takes place at a rate expressed by the **Stefan-Boltzmann** (fourth-power) **law;** while its spectral energy distribution is described by **Wien's laws,** or more accurately by **Planck's distribution law,** as well as by a number of other empirical laws and formulae. (See **thermal radiation.**)

The nearest approach to the ideal black body, experimentally, is an almost completely closed cavity in an opaque body. The laboratory type is usually a somewhat elongated, hollow metal cylinder, blackened inside, and completely closed except for a narrow slit in one end. When such an enclosure is heated, the radiation escaping through the opening closely resembles the ideal black-body radiation; while light or other radiation entering by the opening is almost completely trapped by multiple reflection from the walls, so that the opening usually appears intensely black. For this reason, black-body radiation is also often called "cavity radiation."

BLACK-BODY RADIATION. Radiation having a spectral distribution of energy according to the **Planck distribution law** and such as would be given off by an ideal **black body** or complete radiator. The energy distribution is a function of only the temperature of the radiator.

BLACK COMPRESSION (BLACK SATURATION). In television the reduction in gain applied to a **picture signal** at those **levels** corresponding to dark areas in a picture with respect to the gain at that level corresponding to the mid-range light value in the picture. The gain referred to in the definition is for a signal amplitude small in comparison with the total peak-to-peak picture signal involved. A quantitative evaluation of this effect can be obtained by a measurement of differential gain. The over-all effect of black compression is to reduce contrast in the low lights of the picture as seen on a monitor.

"BLACK OUT" EFFECT. A temporary loss of **sensitivity** of a **vacuum tube** after a strong, short pulse. The effect is extremely variable from tube to tube, and its cause is not understood. It is a different effect from the blocking action due to grid current flow.

BLACK PEAK. In television, a peak excursion of the **picture signal** in the black direction.

BLACK LEVEL. That **level** of the **picture signal** corresponding to the maximum limit of **black peaks.**

BLACKER-THAN-BLACK REGION. In television, the region where the **blanking** and **synchronizing** voltages are found in the video signal. The voltages in this region prevent any electrons in the cathode-ray tube from reaching the viewing screen. The result is an absence of light on the screen.

BLACKETT AND RIDEAL METHOD FOR SPECIFIC HEAT AT CONSTANT PRESSURE. A continuous-flow method, based upon the determination of the **temperature gradient** along a tube through which the gas passes.

BLACKETT RELATION. Empirical relation between magnetic moment μ and angular momentum σ,

$$\mu \sim \frac{G^{1/2}\sigma}{c}$$

(G = gravitational constant) valid for the earth, the sun and the star 78 Vir.

That the relation represents a fundamental property of matter has not been established, and indeed since it was proposed stars have been observed with magnetic moments which vary with time.

BLAGDEN LAW. The depression of the freezing point of a solution is, for small concentrations, proportional to the concentration of the dissolved substance.

BLANK, FINISHED. See **piezoid.**

BLANKED PICTURE SIGNAL. In television, the signal resulting from blanking a **picture signal.** Adding the **sync signal** to the blanked picture signal forms the **composite picture signal.**

BLANKING. In television, the substitution for the **picture signal,** during prescribed intervals, of a signal whose instantaneous amplitude is such as to make the **return trace** invisible. The term is also applied in connection with laboratory **cathode-ray oscilloscopes.**

BLANKING LEVEL. In television, that **level** of a **composite picture signal** which separates the range containing picture information from the range containing synchronizing information. The **setup region** is regarded as picture information.

BLANKING SIGNAL. A wave constituted of recurrent pulses, related in time to the **scanning process,** used to effect **blanking.** In television, this signal is composed of pulses at line and field frequencies, which usually originate in a central sync generator and are combined with the **picture signal** at the pickup equipment in order to form the **blanked picture signal.** The addition of the **sync signal** completes the **composite picture signal.** The blanking portion of the composite picture signal is intended primarily to make the return trace on a picture tube invisible. The same blanking pulses or others of somewhat shorter duration are usually used to blank the pickup device also. (See **pulses, blanking.**)

BLATTNERPHONE. A name given to one form of **magnetic wire recorder.**

BLAZE. It is now possible to rule **diffraction gratings** with lines of predetermined shape so that one side of the groove is a plane, called the blaze.

BLEEDER RESISTANCE. A permanently connected resistor across the output of a **power supply.**

BLEMISH. See **ion blemish, negative.**

BLIND SPOT. The place on the **retina** of the **eye** where there is a lack of sensitivity due to the entrance of the optic nerve.

A ● B ●

Look at A with right eye from a distance of about 6 inches and B is not visible

BLISTER. Colloquialism for a **radome.**

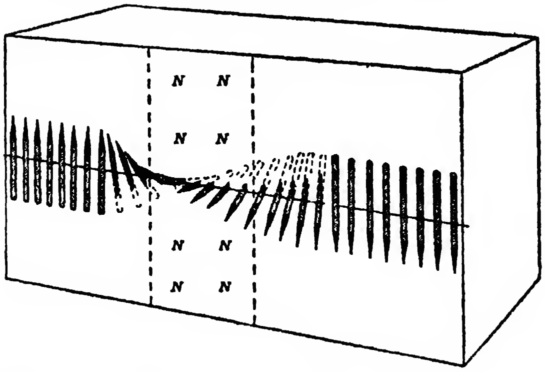
BLOCH FUNCTION. It can be shown that the **wave function** of an electron in a **periodic lattice** has the form

$$\psi = u(\mathbf{r})e^{i\mathbf{k}\cdot\mathbf{r}}$$

where $u(\mathbf{r})$ has the periodicity of the lattice (i.e., is the same in every unit cell) and $\mathbf{k}$ is the **wave vector** of the electron

BLOCH THEOREM. (1) The lowest state of a quantum-mechanical system in the absence of a magnetic field can carry no current; an important result for the theory of **superconductivity.** (2) The statement that every electronic wave function in a periodic structure can be represented by a **Bloch function.** (Bloch's proof was general for solutions of the Schrodinger equation with a periodic potential.)

BLOCH WALL. The transition layer between adjacent ferromagnetic domains magnetized in different directions. The wall has a finite thickness, of the order of a few hundred **lattice constants,** as it is energetically preferable for the spin directions to change slowly from one orientaton to another, going through the wall, rather than to have an abrupt discontinuity.



Bloch wall (By permission from "Introduction to Solid State Physics" by Kittell, Copyright 1953, John Wiley & Sons, Inc.)

BLOCKED IMPEDANCE. The **impedance** of an electromechanical or electroacoustical **transducer** as measured when the mechanical system is blocked to prevent any **motional impedance.**

BLOCKED RESISTANCE. The real part of **blocked impedance.**

BLOCKING. The interruption of **plate current** in a tube due to the application of a high negative voltage. When done intentionally, this may be called **blanking** or **gating.**

BLOCKING CAPACITOR. See **capacitor, coupling or blocking.**

BLOCKING OSCILLATOR. See **oscillator, blocking.**

BLOOM (ON PHOTOGRAPHIC PLATE). A filmy layer deposited on a photographic plate by tap water. Removed by gently rubbing the plate with wet cotton.

BLOOMING. In cathode-ray tubes, the mushrooming of an electron beam (with consequent **defocussing**) produced by too high a setting of the **brightness control.**

BLUE GLOW. (1) A type of **thermoluminescence** emitted by certain metallic oxides when heated. (2) The bluish luminosity of the gas near the cathode in a **Geissler tube.**

BODY CAPACITANCE. The capacitance effect produced when the operator's hand is brought near a vacuum-tube circuit. Since many of these circuits, especially those employing tuned circuits, are very sensitive to small changes in the capacitance coupling to surrounding objects, the bringing of the hand near any of the circuit conductors will materially alter the response of the circuit. Such effects can be minimized by shielding the circuit and by appropriate grounding.

BODY-CENTERED STRUCTURE. A type of **crystal structure** in which atoms are located at the corners and centre of a cubic or rectangular cell. (See **space lattice.**)

BOHM AND PINES METHOD. A technique for allowing for the **Coulomb interaction** between the conduction electrons (see **electron, conduction**) in a metal. It is shown that the gas of electrons behaves as a **plasma,** having characteristic vibrations of long wavelengths but nearly constant frequency, while the interactions between individual electrons are shielded out at all but short distances. The method gives good values for **binding energies,** specific heats, **paramagnetic susceptibilities,** etc. of simple metals, and the plasma oscillations have been observed by noting the energy lost by electrons passed through thin films of the metal.

BOHR FREQUENCY CONDITION. See **Bohr theory of atomic spectra, Postulate 2.**

BOHR MAGNETON. A unit of magnetic moment used in atomic physics. (1) The electronic Bohr magneton is the most widely used form of this unit, and is understood when not otherwise designated. It is defined by the expression:

$$\mu_0 = eh/4\pi m_e c = 9.27 \times 10^{-21} \text{ erg gauss}^{-1},$$

where μ_0 is the electronic Bohr magneton, e is the electronic charge, h is the Planck constant, m_e is the rest mass of the electron and c is the speed of light. (2) The nuclear Bohr magneton is defined by the expression:

$$\mu_1 = eh/4\pi Mc = \frac{\mu_0}{1836},$$

where M is the rest mass of the proton, and the other symbols have the same meanings as those given for the expression for the electronic Bohr magneton.

BOHR RADIUS. In its most common usage, this term designates the radius r_1 of the orbit of the lowest energy in the Bohr model of the hydrogen atom. Its value is given by the expression:

$$r_1 = \frac{h^2}{4\pi^2 m_e e^2}$$

where h is the Planck constant, m_e is the rest mass of the electron, and e is the electronic charge. Sometimes the term Bohr radius is used to designate the radius r_n of any one of the permissible orbits in the Bohr model of the hydrogen atom. Its value is given by the expression:

$$r_n = \frac{n^2 h^2}{4\pi^2 m_e e^2} = n^2 \times 0.529 \times 10^{-8} \text{ cm}$$

where n is the principal quantum number, and the other symbols have the same meaning as those given for the expression for r_1 above.

BOHR THEORY OF ATOMIC SPECTRA. Bohr based this theory of spectral series upon two postulates: Postulate 1. "An atomic system can, and can only, exist permanently in a certain series of states corresponding to a discontinuous series of values for its energy, and hence any change in the energy of the system, including emission and absorption of electromagnetic radiation, must take place by a complete transition between two such states. These states will be called the stationary states of the system." Postulate 2. "That the radiation absorbed or emitted during a transition between two stationary states is monochromatic and possesses a frequency ν, given by the relation $h\nu = E_m - E_n$."

BOHR-WHEELER EMPIRICAL MASS FORMULA. See **mass formula, empirical.**

BOHR-WHEELER THEORY. An analytical theory of the nature of nuclear fission and the conditions under which it might occur, based upon a liquid-drop analogy. One conclusion was that if the ratio Z^2/A exceeded 45, no additional energy would be necessary to cause fission to take place. (Z = atomic number; A = mass number.) An element having a Z^2/A ratio of 45 would have an atomic number of well over 100, so according to this theory, elements of atomic number appreciably higher than 100 are not stable.

BOILING. The process of changing from the liquid state to the vapor state, the term being restricted usually to cases in which the vapor pressure of the liquid is equal to, or greater than, the atmospheric pressure above the liquid.

BOILING MIXTURES, CONSTANT. Liquids consisting of two or more **components** which boil at constant temperature and distill without change in composition. Commonly, there is only one composition at which two particular liquids form a constant boiling mixture. (The proportions vary, of course, with the pressure.) Constant boiling liquid systems are also called **azeotropic** mixtures.

BOILING POINT. The normal boiling point of a **liquid** is the temperature at which its maximum or "saturated" **vapor pressure** is equal to the normal **atmospheric pressure,** 760 mm of mercury. If the pressure on the liquid varies, the actual boiling point varies in accordance with the relation between the vapor pressure and the temperature for the liquid in question. (See **vapors.**) Water, for example, with a normal boiling point of 100°C or 212°F, boils at ordinary room temperature when the pressure is reduced to about 17 mm. If a solid is dissolved in the liquid, or if another, less volatile liquid is mixed with it, the boiling point is raised to a degree expressed by the boiling point laws of van't Hoff, Raoult, and others. (See **solutions.**)

A liquid does not necessarily begin boiling when the temperature reaches the boiling point. If kept perfectly quiet, and especially if covered with a film of oil, water may be raised several degrees above its normal boiling point, before it suddenly boils with explosive violence; it then returns to its true boiling point. (See **ebullition.**)

BOILING POINT, ABSOLUTE. The boiling point on the **absolute scale,** numerically equal to the boiling point in degrees centigrade plus 273.16°.

BOILING POINT, CONSTANT. The temperature at which a **solution** boils without a change in composition, at a definite concentration and under a constant pressure; the proportion by weight of the **components** in the vapor is the same as in the liquid.

BOILING POINT ELEVATION BY DISSOLVED SOLUTE. For dilute solutions the amount of elevation is given approximately by the relationship:

$$\Delta T = \frac{kn_2}{n_1 + n_2}$$

where ΔT is the elevation in boiling point, k is a constant, and n_1 and n_2 are the number of moles of solvent and solute respectively.

BOILING POINT, MAXIMUM. Binary liquid systems which show negative deviations from the **Raoult law** have vapor pressure-composition curves at constant temperature which pass through a minimum. For these systems the boiling point-composition curve at constant pressure passes through a maximum. At the maximum boiling point the liquid and vapor have the same composition and such a solution (azeotropic solution) distils completely without change in composition or temperature.

BOILING POINT, METHOD(S) FOR DETERMINING ELEVATION OF. In the Beckmann method a Beckmann-type thermometer is immersed in a weighed amount of solvent and the boiling point determined by gentle heating until a steady temperature is reached. A weighed amount of solute is then added and the boiling point redetermined. The difference gives the elevation of the boiling point. The glass vessel containing the liquid is provided with a platinum wire sealed through the bottom to promote steady boiling and to prevent overheating, and reflux condensers are used to minimize loss of liquid.

In the Landsberger method, vapor from boiling solvent is passed through the solvent contained in another vessel and by giving up its **latent heat** will eventually raise the liquid to the boiling point. At this stage a weighed amount of solute is added to the second vessel and the boiling point is again determined.

In the Cottrell method, the thermometer is placed in the vapor phase above the surface of the liquid and the apparatus so designed that boiling liquid is pumped continuously over the bulb of the thermometer.

BOILING POINT METHOD FOR VAPOR PRESSURE. A simple method depending on the fact that a liquid boils when its vapor pressure is equal to the external pressure. The liquid is heated in a vessel which is connected through a condenser to a pump and a suitable manometer. Condensed vapor runs back into the liquid, and the pressure is controlled by the rate of pumping. The temperature of the liquid is adjusted until it boils. The method is applicable over a wide range of temperature and pressure.

BOILING POINT, MINIMUM. Binary liquid systems which have vapor pressure-composition curves at constant temperature that pass through a maximum, give boiling point-composition curves at constant pressure that pass through a minimum. At the minimum boiling point the liquid and vapor have the same composition. (See **maximum boiling point.**)

BOILING POINT OF SOLUTIONS. The solution of a nonvolatile substance in a liquid lowers the **vapor tension** of the system and so raises the boiling point of the solvent. In dilute solutions the effect is proportional to the molecular ratio between the solvent and solute but in concentrated solutions deviations from this rule occur. (See **law of Raoult.**)

BOLOMETER. A very sensitive **thermometric** instrument of the metallic **resistance** type, devised by Langley and used for measuring feeble **radiation.** It consists of a slender strip of platinum mounted at the lower end of a long cylindrical tube having circular stops across it at intervals to screen off all radiation except that to be observed. A slight amount of radiant energy falling upon the strip causes a measurable deflection in a sensitive galvanometer in the resistance **bridge** coupled with it. The sensitivity of the instrument is of the same order as that of the **radiomicrometer** of Boys When a bolometer tube is mounted as the receiving element of a spectroscope, instead of the usual observing telescope or camera, the instrument may be used to detect and measure the intensity of **infrared** spectral lines or bands. Very sensitive bolometers have been constructed, making use of the rapid resistance change when a metal becomes **superconductive.**

In microwave technology, a **barreter, thermistor** or other device utilizing the temperature coefficient of resistivity of some resistance element is called a bolometer.

BOLTZMANN CONSTANT. The constant k in the calculations arising in the development of the **Boltzmann principle.** The least squares adjusted output value of this constant is

$$(1.38026 \pm 0.000022) \times 10^{-16} \text{ erg deg } C^{-1}.$$

The Boltzmann constant is equal to the **ideal gas constant** per mole (R) divided by the **Avogadro number.**

BOLTZMANN FACTOR. A correction factor applied to calculated line intensities in spectra due to thermal excitation.

BOLTZMANN PRINCIPLE. A somewhat general law relating to the statistical distribution of large numbers of minute particles subject to thermal agitation and acted upon by a **magnetic,** an **electric,** or a **gravitational field,** or by **inertia.** The number of particles per unit volume in any region of the field, when the system is in statistical **equilibrium,** is given by the equation

$$N = N_0 e^{-\frac{E}{kT}}.$$

Here E is the **potential energy** of a particle in the given region, N_0 is the number per unit volume in a region of the field where E is zero, k is the Boltzmann constant (ideal gas constant per molecule), and T is the absolute temperature of the system of particles Such an equilibrium may exist, for example, in a mass of electrified colloidal particles kept in suspension by their **Brownian movement** while acted upon by an electric field.

BOLTZMANN TRANSPORT EQUATION. The fundamental equation describing the conservation of particles which are diffusing in a scattering, absorbing, and multiplying medium. It states that the time rate of change of particle density is equal to the rate of production, minus the rate of leakage and the rate of absorption.

BOMBARD. To subject to the impact of particles or radiations, as is used in the production of other particles or radiations, or in the **transmutation** of atoms.

BOND. A symbol used to denote the number and attachments of the valences of an atom in constitutional formulas. The bond is represented by a dot (·) or line (—) drawn between the atoms, as H·O·H or H—O—H Double and triple bonds are used also and may express unsaturation, particularly when they join two atoms of the same element Examples, =C =O, $H_2C=CH_2$, Ca=O, HC≡CH. The nature of the valence bond is considered to be electrical attraction attributable to various distributions of the electrons around the nuclei of the bonded atoms. Various arrangements of this kind, and their influence upon the properties of the resulting compounds, are discussed for the special types of bonds which follow.

BOND ANGLE. The angle between two **bonds** in a molecule, e g., in water the bond angle is 109 5°, indicating that the lines joining the two hydrogen atoms to the oxygen atom meet at this angle. (See **bond direction.**)

BOND, ATOMIC. A **valence** linkage between atoms consisting of a pair of electrons, one of which has been contributed by each of the atoms bonded.

BOND, COORDINATE. A term applied to various types of **valence** bonds. The most common usage occurs probably in the case of the semicovalent bond formed between two atoms by a pair of electrons, both donated by one of the atoms, or in the special case of a coordination-type compound, in which the primary valences have already been satisfied, and in which the coordinate bond is formed later.

BOND, COVALENT. A type of linkage between atoms wherein each atom contributes one electron to a shared pair that constitutes an ordinary chemical bond

BOND, DATIVE. A type of covalent bond (see **bond, covalent**) in which both electrons forming the bonding pair are supplied by one atom. An example is the forming of amine oxides between tertiary amines and oxygen, in which both electrons were donated by the nitrogen group Such bonds exhibit some polarity and are frequently called semipolar bonds.

BOND DIRECTION, OR ORIENTATION. Certain covalent bonds (see **bond, covalent**) prefer to lie in particular directions with respect to the bonded atoms For example, the bonds from carbon point from the center to the vertices of a regular tetrahedron. (See **directed covalent bond; bond angle.**)

BOND, ELECTROSTATIC. A **valence** linkage in which two atoms are held together by **electrostatic forces** resulting from the transfer of one or more electrons from the outer shell of one atom to that of the other. In this process the atoms are converted into **ions** of opposite charge which attract each other. The transfer of electrons is commonly in the direction that gives completed, or more

nearly completed, outer electron shells for both atoms.

BOND ENERGY. The energy characterizing a chemical bond between atoms, as measured by the energy required to disrupt it.

BOND, HETEROPOLAR. A **valance** linkage, between two atoms, consisting of a pair of electrons. This bond is characterized by an unequal distribution of **charge** due to a displacement of the electronic-pair so that the effect of the bond is to make one atom differ in polarity from the other.

BOND, HOMOPOLAR. A **valence** linkage between two atoms consisting of a pair of electrons that are held equally by both atoms, so that no difference in polarity exists between the atoms.

BOND, HYDROGEN. A **valence** linkage joining two electronegative atoms through a hydrogen atom Since a stable hydrogen atom cannot be associated with more than two electrons, the hydrogen bond may be regarded as representing a **resonance** phenomenon, by which it is alternatively attached to one or the other of the two atoms.

BOND, IONIC. See **bond, electrostatic.**

BOND, METALLIC. A special type of bond existing in **metals**, in which the **valence** electrons of the constituent atoms are free to move in the periodic lattice. This type of bonding accounts for the observed metallic properties.

BOND, MOLECULAR. A **valence** linkage between two atoms consisting of a pair of electrons, both of which have been furnished by one of the atoms

BOND MOMENT. The electrostatic dipole moment of a chemical bond between atoms.

BOND, SEMI-COVALENT OR BOND, POLARIZED IONIC. A **valence** linkage which is intermediate in character between a purely ionic and purely covalent **bond**, with intermediate properties. Such bonds arise quite often if the constituent atoms have unequal electron affinities.

BOND, SEMIPOLAR. See **bond, dative.**

BOND STRENGTH. The energy required to rupture a given valence **bond** in a given molecule.

BOND SYSTEM OF NOTATION. A system of notation proposed by Bond for the description of the cut of a **piezo-electric crystal.**

BONDING ORBITAL. A **molecular orbital** coupling two atoms in such a way that the energy has a minimum value when the interatomic distance is small, thus favoring a **bond** between them.

BONE CONDUCTION. The process by which sound is conducted to the inner ear through the cranial bones.

BOOST. To increase or amplify.

BOOSTER. An electrical booster is one of several types of devices inserted in series in an **electric circuit,** to increase the **voltage** of that circuit. There are several uses to which the booster can be put. It may be employed to compensate for a line voltage drop, or it may be employed to vary voltage in such a way that constant current is maintained The boosting of d-c circuits is accomplished by rotating equipment called booster generators. If this booster is driven by an electric motor the set is called a motor-booster. The booster generator can be used to raise the line voltage at a feeder point on an electric traction system.

The booster transformer is sometimes used in **alternating-current circuits.** On a simple single-phase circuit it boosts the line voltage by connecting the primary of the **transformer** across the line, and the secondary in series. The **induction regulator** is a form of booster transformer whose effect is varied by rotating one winding with respect to the other.

The term booster is widely used as a colloquialism for an **amplifier** between the antenna and receiving set (especially a television set) antenna terminals.

BOOSTER VOLTAGE. In the **deflection circuits** of television receivers, the additional d-c voltage added to the **plate supply voltage** by the **damper tube.**

BOOTHROYD-CREAMER SYSTEM. A time-division **multiplex modulation system.**

BOOTSTRAP CIRCUIT. A single-stage **amplifier** in which the output load is **connected** between the negative end of the **plate supply**

and the cathode, the signal voltage being applied between the **grid** and the cathode. The name "bootstrap" arises from the fact that a change in grid voltage changes the potential of the input source with respect to ground by an amount equal to the output signal.

BORDA MOUTHPIECE, OR NOZZLE. An outlet from a container of liquid by a short re-entrant tube. The **discharge coefficient** of the Borda mouthpiece is exactly one-half, and a measurement of the head and the orifice area is sufficient to compute the total flow.

BORN APPROXIMATION. Method of computing approximately the wave-functions and cross-section in the **quantum mechanics** of collision processes, chiefly applicable when the interaction energy between the colliding particles is small compared with their kinetic energy. Thus the first Born approximation corresponds to keeping terms of first order in the interaction energy which is treated as a perturbation to the **Hamiltonian** of the system.

BORN-HABER CYCLE. A cycle of changes, chemical and physical, applied to a chemical substance, commonly a crystalline metallic halide to calculate the electron affinities of certain atoms. The stages include the dissociation of the molecules of the crystal into gaseous ions, the neutralization of these ions by transfer of electrons from the negative ions to the positive ones, the condensation of the gaseous atoms to form solid molecules of the two substances (e.g., metal and halogen), and the recombination of the solid molecules to reform the original crystalline compound. From this cycle, it is possible to derive the equation

$$E = Q + S + \frac{D}{2} + I - U_{MX}$$

in which E is the electron affinity of the halogen atoms, Q is the heat of formation of the compound, S is the heat of sublimation of the metal, D is the heat of dissociation of the molecular halogen, I is the ionization potential of the metal, and U_{MX} is the **lattice energy** of the crystal. (See **Born-Mayer equation.**)

BORN-HEISENBERG REPRESENTATION. See **Heisenberg representation.**

BORN-INFELD THEORY. Non-linear modification of **Maxwell equations** in which the electromagnetic field is described by four vectors **E, B, D, H**, two of which are functions of the other two. Leads to a finite energy for an electric particle, but it is not a unique theory and it does not lead to new results which may be compared with those of experiment.

BORN-MAYER EQUATION

$$U = \frac{a^2\epsilon^2NA}{r} - bc^{-rp} + \frac{c}{r^6} + \epsilon_0.$$

This equation represents the **binding energy** of an **ionic crystal** as the sum of various terms. The first is the **Coulomb energy** of the lattice of charged ions. Next comes the repulsive potential between the outer closed shell of the ions. The third term comes from the **van der Waals forces** of attraction between them. ϵ_0 is a constant, depending on the choice of the zero of energy. In each case, r is a measure of the interatomic distance, or **lattice constant,** and its equilibrium value makes U a minimum.

BORN-OPPENHEIMER METHOD. An argument for calculating the **force constants** between atoms in a molecule or solid, based on the observation that the motion of the electrons is so rapid compared with that of the heavier nuclei that it can be assumed that the electrons follow the motion of the nuclei adiabatically. That is, one calculates the eigenvalues of energy for the electrons with the nuclei in fixed positions, the variation of this electronic energy with the configuration of the nuclei may then be treated as a contribution to the potential energy of the interatomic forces.

BORON. Nonmetallic element. Symbol B. Atomic number 5.

BOSE-EINSTEIN STATISTICS. See **quantum statistics.**

BOSE-EINSTEIN STATISTICS APPLIED TO PHOTONS. In the application of statistical theory to photons certain changes must be made from the assumptions of the classical Maxwell-Boltzmann statistics, namely: the number of photons is not fixed, although the total energy is fixed, and photons are not distinguishable individuals. Based upon these assumptions, the Bose-Einstein statistics apply to photons.

BOSON. A particle described by Bose-Einstein statistics. (See **quantum statistics.**)

BOTTOMING. The process of **clamping** the plate potential of a **pentode** at a low level by operating below the knee of the E_p/I_p characteristic. A **triode** operated in the **positive grid region** may be operated in a similar manner.

BOUGUER LAW (1729) (LAMBERT LAW OF ABSORPTION). In materials that are homogeneous such as glass or clear liquids the absorption of radiant energy depends on the thickness in accordance with the Bouguer law,

$$\frac{dI}{dx} = -kI \quad \text{or} \quad I = I_0 e^{-kx}$$

where I is the intensity of light transmitted, I_0 is the intensity of incident light, x is the thickness of transmitting layer, and k is known as the **absorption coefficient,** and is equivalent to $\varkappa c$ of the **Beer law.** The Bouguer law was first set forth by Bouguer, but was rediscovered by Lambert, and is frequently called the Lambert law of absorption.

If written

$$I = I_0 10^{-ax},$$

a is known as the **extinction coefficient** of the substance.

These laws may be applied to a narrow band of wavelengths, giving the specular coefficient of absorption or the specular extinction coefficient according to the form of the equation used.

BOUNDARY CIRCLES. In **impedance matching,** circles of constant **standing-wave ratio** which represent the boundaries of all **transformation circles** which may be transformed to the **definition circle.**

BOUNDARY CONDITION. Specified values of the solution to a **differential equation** and its derivatives for certain values of the independent variables which make the solution acceptable, usually in order to satisfy some conditions imposed for physical reasons. For a **total differential equation,** the boundary conditions specify the values of the arbitrary constants in the **general solution.** In the case of a **partial differential equation,** the boundary conditions affect the form of the solution. Sometimes boundary values lead to **eigenfunctions.** Commonly occurring types of boundary conditions are those of **Dirichlet, Neumann, Cauchy, homogeneous,** and **standard.**

BOUNDARY CONDITION, HOMOGENEOUS. As applied to a **partial differential equation,** these conditions consist of the specification of the value of the function $\phi(s)$ and its normal derivative $N(s)$ along a bounding surface in such a way that $A\phi(s) + BN(s) = 0$. When $A\phi(s) + BN(s) = F(s)$ the conditions are **inhomogeneous.** In either case, they are called **Cauchy boundary conditions.**

BOUNDARY CONDITION, STANDARD. When applied to the **Schrödinger equation** of quantum mechanics, this condition requires that the wave function and its derivative vanish at infinity.

BOUNDARY, P-N. A surface in the transition region between P-type and N-type material at which the donor and acceptor concentrations are equal. (See **semiconductor, N-type; semiconductor, P-type; donor impurity;** and **acceptor impurity.**)

BOUNDARY LAYER, FLUID FLOW. Motion of a fluid of low viscosity, such as air or water, around a stationary body or through a stationary conduit possesses the free velocity of an ideal fluid everywhere except in an extremely thin layer immediately next to the stationary body. Many of the phenomena of fluid flow may be studied and analyzed without consideration of this boundary layer, but, thin as it may be (usually a few thousandths of an inch), its internal mechanics must be understood and evaluated in certain of the phenomena of fluid motion. Some of the more important of these are:

1. The magnitude of the maximum lift coefficient of the airfoils.
2. Profile drag of airfoils.
3. The drag of bluff bodies.
4. The large variations of drag coefficient at critical Reynolds number for laminar-turbulent transition.
5 The transfer of heat through surface films.

Many of the phenomena of the boundary layer are explainable on the basis of the theory advanced by Prandtl at the great University of Göttingen laboratory nearly half a century ago. In the same flow-research

group were others, like Blasius, who broadened and experimentally confirmed the original hypotheses.

BOUNDARY, P-N (SEMICONDUCTORS). A surface in the transition region between **P-type** and **N-type** material at which the **donor** and **acceptor** concentrations are equal

BOUNDARY METHOD, MOVING. See **moving boundary method.**

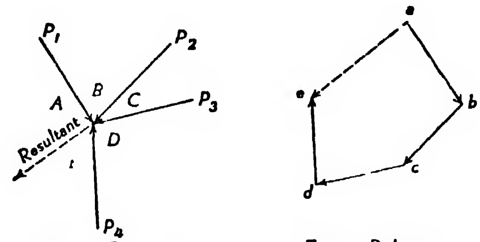
BOUNDARY METHOD, SHEARED. See **sheared boundary method.**

BOUNDARY SCATTERING (OR BOUNDARY RESISTANCE). In **thermal conduction in solids,** at low temperatures the **phonon mean free path** may become so large that it exceeds the dimensions of the specimen In this case, the conductivity is limited by scattering of the phonons by the boundaries, and appears to depend on the size of the sample.

BOUNDED. A function such that for all values of the function, $f(z) < M$, where M is a real positive number, is said to be bounded from above When $f(z) > M$ (M negative), it is bounded from below. When $|f(z)| < M$, the function is of bounded variation Similar definitions are applicable when $f(z)$ is replaced by a **set** or **sequence.**

BOURDON GAUGE. A device for measuring pressure in which a positive pressure difference between the outside and inside of a curved tube of flattened section tends to straighten it The movement may be linked to a dial and pointer indicator, although other methods of indication are used

BOW NOTATION. Bow's notation is a standard method of representing, by letters of the alphabet, forces and **stresses** in graphical analysis. This analysis may consist of such problems as the graphical solution of stresses in simple framed structures or the determination of the **resultant** of an independent system of unbalanced forces lying in the same plane and having a common point of application The accompanying figure illustrates the method of applying Bow's Notation to the latter system Let P_1, P_2, P_3 and P_4 be a system of unbalanced forces lying in the same plane and having a common point of application. Denote the space between the line of action of each force by the letters A, B, C and D Next construct a figure called a force polygon. This is accomplished by drawing a line parallel to P_1 and laying off its magnitude to a definite scale denoting the ends of the line by the letters a and b. From point b lay off bc equal in magnitude and



Force System   Force Polygon

parallel to P_2. Repeat the operation for the other forces. Upon completion of this graphical figure it will be found, in general, that the line representing P_1 will not pass through point a. The distance from point a to end of this line, which will be lettered e, represents the value of the resultant of P_1, P_2, P_3 and P_4 according to the scale used The direction of ae determines the line of action of the resultant Thus, in Bow's Notation a force in space is designated by the space letters on either side of it, whereas the forces as part of the force polygon are named by the letters at their extremities This notation is further illustrated in the accompanying figure

"BOX-CAR" LENGTHENER. A pulse-lengthening circuit which lengthens a series of **pulses** without changing their height. Ideally, it produces flat-topped pulses prolonged throughout the interval between pulses

BOYLE-CHARLES LAW. The **Boyle law** expresses the variation of pressure and volume of a body of ideal **gas** at constant temperature; the **Charles law** expresses the proportionality of pressure to absolute temperature (at constant volume), while the Gay-Lussac law states the proportionality of volume to absolute temperature (at constant pressure).

A single statement covering all these relationships is the Boyle-Charles law, which leads to, or is a form of, the **ideal gas law.** Its mathematical expression may be written:

$$pv = p_0v_0(1 + at),$$

in which p_0v_0 is the value of pv at temperature $t = 0$, and a is the volume coefficient of expansion for the gas in question. If the centigrade

scale is used, a is for all gases approximately equal to $1/273$ or 0.003663 per centigrade degree.

BOYLE LAW. (Mariotte law, law of Boyle-Mariotte.) At constant temperature the volume of a gas varies inversely as the pressure, and the pressure varies inversely as the volume. In other words, the product of the pressure and volume of a gas is constant at a given temperature. This law holds only for the ideal or perfect gas; all real gases depart from it to a greater or lesser extent.

BOYLE TEMPERATURE. The temperature, for a given gas, at which the **Boyle law** is most closely obeyed in the lower pressure range. At this temperature the minimum point (of inflection) in the pV–T curve falls on the pV axis.

BRA VECTOR. The **dual** of a **ket vector,** denoted by the symbol $\langle B|$. The scalar product of a bra and a ket is the bracket $\langle B|A\rangle$.

BRACE-LEMON SPECTROPHOTOMETER. A spectrophotometer which has two identical collimators, in one of which are set two Glan polarizing prisms, one fixed in azimuth while the other may be rotated. The dispersive element is a Brace prism.

BRACE PRISM. A compound prism made of two 30-degree prisms. On one of these is deposited an opaque coat of suitable metal of high reflecting power which covers only part of the prism-face. The two prisms are then sealed together with Canada balsam so that the reflecting coat is between the two halves of the compound prism.

BRACHISTOCHRONE. The characteristic curve along which a particle will slide from one point to another under the influence of gravity in the least possible time, friction being neglected. The formal solution is obtained by an application of the **calculus of variations.** The curve has the mathematical form of a **cycloid.**

BRACKETT SERIES. A group of lines in the **infrared spectrum** of atomic hydrogen represented by the formula:

$$\bar{\nu} = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

in which $\bar{\nu}$ is the **wave number,** R_H is the Rydberg number for hydrogen (109,677.591 cm^{-1}), n_1 is 4, and n_2 has various integral values.

BRADLEY ABERRATION METHOD. Because of the finite ratio between the velocity of light and the velocity of the earth in its orbit, a telescope aimed at a star must be pointed slightly forward in order to correct for the forward motion of the telescope while light is moving the length of the telescope. Bradley (1728) found the maximum **angle of aberration** to be about 20.5 seconds of arc. This combined with the velocity of the earth in its orbit gives the approximate velocity of light. (See, however, the **Airy experiment.**)

BRAGG ANGLE. See **Bragg equation.**

BRAGG CURVE. (1) A graph for the average number of ions per unit distance along a beam of initially monoenergetic **α-particles,** or other ionizing particles, passing through a gas. (2) A graphical relationship between the average specific ionization of an ionizing particle of a particular kind, and some other variable, such as the kinetic energy, the residual range, or the velocity of the particle.

BRAGG EQUATION. See **Bragg law.**

BRAGG LAW. The law expressing the condition under which a **crystal** will reflect a beam of x-rays with maximum distinctness, at the same time giving the angle at which the reflection takes place. This law is also valid for the reflection of de Broglie waves associated with electrons, protons, neutrons, etc. For x-ray reflection it is customary to use the complement of the angle of incidence and reflection, that is, the angle which the incident or the reflected beam makes with the crystal planes, rather than with the normal. Let this "Bragg angle" be θ. If the planes or layers of atoms are spaced at a distance d apart, and if λ is the wavelength of the x-rays, Bragg's law is expressed by the equation

$$\sin\theta = \frac{n\lambda}{2d}.$$

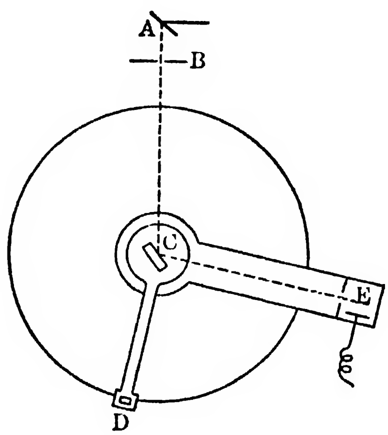
The condition for an intensity maximum is that n must be a whole number. For example if the planes of rock salt parallel to the natural cubical faces are spaced at $d = 2.814 \times 10^{-8}$ cm or 2814 x-units, and if the incident rays have a component of wavelength $\lambda = 714$ x-units, the above equation gives $\sin\theta = 0.1269n$.

Then if the crystal is rotated slowly, there will be a distinct reflection when θ reaches 7° 17′ ($n = 1$), again at 14° 42′ ($n = 2$), also at 22° 23′ ($n = 3$), etc.

BRAGG METHOD OF CRYSTAL ANALYSIS. A beam of **x-rays** is directed against a **crystal,** and its atoms, because of their **lattice** arrangement, reflect the rays as would a series of plane surfaces. The measurements of the **diffraction patterns** formed by the reflected radiations furnish a means of calculating the spacings between the **atomic planes,** if the wave length of the x-rays is known.

BRAGG RULE. An empirical relationship whereby the mass **stopping power** of an element for α-particles is inversely proportional to the one-half power of the atomic weight. This relationship is also stated in the form that the atomic stopping power is directly proportional to the one-half power of the atomic weight. The wide usefulness of the Bragg rule is due to the fact that it leads to relations between the stopping powers of different elements for α-particles. It also applies to other charged particles as well as α-particles, and to the same degree of approximation.

BRAGG SPECTROMETER (OR IONIZATION SPECTROMETER). An instrument for the **x-ray analysis** of **crystal structure,** in which a homogeneous beam of x-rays is directed on the known face of a crystal, C, and



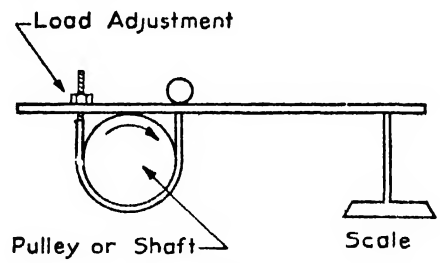
Bragg spectrometer

the reflected beam detected in a suitably placed **ionization chamber,** E. As the crystal is rotated, the angles at which the **Bragg equation** is satisfied are identified as sharp peaks in the ionization current. See figure.

BRAGG TREATMENT. The discussion of the diffraction of **x-rays** by **crystals** in which it is shown that interference between rays reflected from successive **atomic planes** leads to the Bragg equation. (See **Bragg law.**)

BRAKEFIELD OSCILLATOR. A positive-grid, electron-tube oscillator usable to 10,000 megacycles.

BRAKE HORSEPOWER. The mechanical output of an engine, turbine, or motor is called the brake horsepower because one of the most common methods of testing for mechanical output is with the Prony brake. However, the output available at the shaft is called brake horsepower whether measured by brake or not. For example, when an engine drives an electric generator by direct connection, the horsepower available at the coupling between the machines is termed brake horsepower, but would not, under these circumstances, be measured by a brake. In the case of direct connected electric generating sets, the brake horsepower of the prime mover is found by dividing the electrical output from the generator, converted to horsepower, by the efficiency of the generator. The result is the generator input, which is the same as the mechanical output of the prime mover.



Prony brake

To measure brake horsepower by a Prony brake, readings of the weight registered on the scales and the speed of rotation of the brake drum are taken. In addition, the measured distance from the center of rotation to the force on the scales must be known. These quantities are substituted in the following formula to obtain brake horsepower:

$$\text{Brake horsepower} = \frac{2\pi WRN}{33{,}000}$$

W = net load on the scales, in pounds.
R = radial distance in feet to the line of action of the force registered on the scales.
N = rotative speed, in revolutions per minute.

The W of the above formula is less than the load actually recorded on the scales because the tare weight must be deducted from the scale reading to give net effective weight. The tare weight is an allowance for the fact that the arm of the Prony brake itself gives some reading on the scale due to its unbalanced position, relative to the center of rotation. The tare weight is that weight which, acting at the scales, will give the same moment about the center of rotation that the unbalanced dead weight of the brake would produce.

BRAKING, DYNAMIC. Braking an electromechanical system involving an electric motor, by forcing the motor to act as a generator and thus to absorb rotational energy.

BRANCH (ARM). A portion of a **network** consisting of one or more two-terminal elements in series.

BRANCH POINT. (1) When a function, $f(z)$ is multivalued, it possesses certain discontinuities called branch points. **Analytic continuation** between two points will then give different values for $f(z)$ if the two paths include a branch point. Branch points always occur in pairs. The line joining them is a **branch line** and a **contour** crossing a branch line changes from one set of values of $f(z)$ to another. The two (or more) independent values of $f(z)$ are its branches. The values of the different branches of $f(z)$ are identical at a branch point. See also **Riemann surface.** (2) See **node.**

BRANCH TRANSMISSION. The transmission of sound in a tube or conduit containing one or more side branches.

BRANCHING. In radioactivity, branching denotes the occurrence of more than one mode of radioactive disintegration of a radionuclide An individual atom of a nuclide exhibiting branching disintegrates by one mode only.

BRANCHING FRACTION. In a radionuclide undergoing disintegration by more than one mode, the ratio of the number of atoms disintegrating by a particular mode to the total number of atoms disintegrating (per unit time), is the branching fraction for the particular mode of disintegration.

BRANCHING RATIO. The ratio of two specified **branching fractions.**

BRASHEAR-HASTINGS PRISM. See **prism, Brashear-Hastings.**

BRAUN TUBE. An early form of **cathode-ray tube.**

BRAVAIS LATTICE. See **space lattice.**

BRAVAIS-MILLER INDICES. A modification of the **Miller indices** suitable for describing hexagonal crystals. In this system, three axes are taken, perpendicular to the **hexagonal axis** and at angles of 120° to one another. The symbols then consist of the reciprocal intercepts on these axes, followed by the reciprocal intercept on the hexagonal axis, all reduced to integers, e.g., (0001). The first three indices are not independent but must add to zero.

BREAKDOWN VOLTAGE. The voltage necessary to cause the passage of appreciable electric current without a connecting conductor. It is commonly used to express the voltage at which an insulator or insulating material fails to withstand the voltage and ceases to behave as an insulator.

BREAK-IN KEYING. See **keying, break-in.**

BREAK IN OPERATION. A communication system which permits the receiving operator to break-in or interrupt the transmission at any time.

BREAKOFFSKI. A colloquial expression for a device used to connect two parts of a glass vacuum system. The two parts are separated by a thin membrane or tip of glass, which may be broken by dropping a weight onto it. The weight is often made of iron, so that it can be lifted by a magnet and then dropped.

BREAK POINT. A point in a program at which a special instruction is inserted which, if desired, will cause a **digital computer** to stop for visual check of progress during the initial checking of a problem.

BREEDING RATIO (NUCLEAR REACTOR). The number of fissionable atoms produced per fissionable atom destroyed.

BREIT-WIGNER FORMULA. An equation relating the cross section σ of a particular nuclear reaction to the energy E of the incident particle and the energy E_0 of a resonance level of the compound nucleus when E is close to E_0 In the special case where only one resonance level is involved, the Breit-Wigner formula is

$$\sigma(a,b) = (2l + 1)\pi\lambda^2 \cdot \frac{\Gamma_a\Gamma_b}{(E - E_0)^2 + (\frac{1}{2}\Gamma)^2}$$

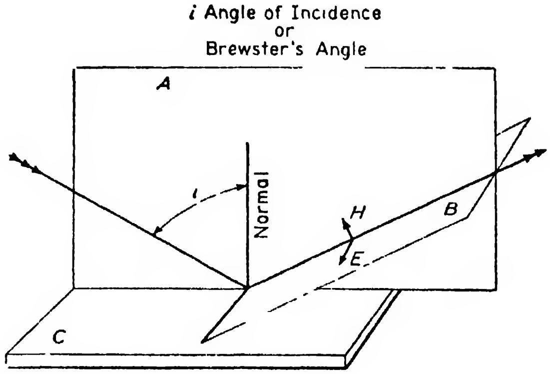
where $\sigma(a,b)$ is the cross section for the reaction involving the capture of particle a and the emission of particle b, Γ_a is the partial width of the energy level for the mode of disintegration in which the incident particle is re-emitted without loss of energy, Γ_b is the partial width of this energy level for the mode of disintegration in which particle b is emitted, Γ is the total width of the energy level, λ $\lambda/2\pi$, where λ is the de Broglie wavelength of the incident particle, and l is the orbital angular momentum quantum number of the incident particle. (See **level width.**)

BREMSSTRAHLUNG. A German word, meaning literally "braking radiation," denoting the process of producing an electromagnetic radiation (or the radiation itself), by the acceleration that a fast charged particle, such as an electron, undergoes when it is deflected by another charged particle, such as a nucleus. The resulting radiation has a continuous spectrum, as exemplified by the continuous x-ray spectra. Outer bremsstrahlung is a term applied in cases where the energy loss by radiation exceeds greatly that by ionization as a stopping mechanism in matter; a phenomenon seen clearly for electrons with energies above 50 mev. Inner bremsstrahlung is a term applied to comparatively infrequent processes occurring in **β-disintegration,** and resulting in the emission of a photon of energy less than (or equal to) the maximum energy available in the transition. The abrupt change in the electric field in the region of the nucleus of the atom undergoing disintegration sometimes results in the production of a photon, in a manner similar to the emission of a photon in the ordinary (outer) bremsstrahlung process. In both negative electron and positron emission the photon energy is obtained at the expense of the electron-neutron pair, and the spectral distribution decreases continuously with increasing energy of the β-particles. In electron capture, the photon energy is obtained at the expense of the neutrino, and the spectral distribution is greatest at about one-third of the normal neutrino energy, reaching zero at zero energy and at the normal neutrino energy. Betatropic substances sometimes exhibit a weak radiation with continuous spectrum that is due to both outer and inner bremsstrahlung, or to one of them alone.

BREWSTER ANGLE. The Brewster angle, or polarizing angle, of a **dielectric** is that **angle of incidence** for which a wave **polarized** parallel to the plane of incidence is wholly transmitted (no reflection). An unpolarized wave incident of this angle is therefore resolved into a transmitted partly-polarized component and a reflected perpendicularly-polarized component. (See **Brewster law.**)

BREWSTER FRINGES. In a single **Fabry-Perot interferometer,** it is not practicable to observe fringes with white light. However, two Fabry-Perot interferometers in series and with their planes not quite parallel will form white-light fringes if the air-spaces of the two are very accurate, integral multiples of each other.

BREWSTER LAW. In 1815 Sir David Brewster discovered that for any dielectric reflector there is a simple relationship between the polarizing angle (see **polarized light)** for the reflected light of a particular wavelength and the **refractive index** of the substance for the same wavelength. The re-



Brewster Law

A, Incident plane (plane of polarization or plane of magnetic vector, after reflection); B, Plane of vibration (plane of electric vector, after reflection); C, Reflecting surface (dielectric).

lationship is that the tangent of the polarizing angle is equal to the refractive index. For example, if the refractive index of flint glass for sodium light is 1.66 the polarizing angle for the reflection of sodium light by this glass is 50° 56′.

BRIDGE. As used in this book, the word bridge without qualification means an electric bridge. (See **bridge, electric.**)

BRIDGE AMPLISTAT. See various bridge circuits listed for **amplifier, magnetic.**

BRIDGE, ANDERSON. A six-element modification of the Maxwell-Wien bridge (see **bridge, Maxwell-Wien**) which has two independent balance conditions. It is used for measuring inductance in terms of capacitance and resistance.

BRIDGE, CALLENDAR AND GRIFFITHS. A slide-wire bridge (see **bridge, slide-wire**) for the measurement of a four-terminal, resistance thermometer.

BRIDGE, CAMPBELL. A **bridge** specifically designed for the comparison of **mutual inductances.**

BRIDGE, CAMPBELL-COLPITTS. An a-c bridge designed to measure capacitance by the **substitution method.**

BRIDGE, CAPACITANCE. A bridge for comparing two **capacitances.**

BRIDGE, CAREY-FOSTER. A form of Wheatstone bridge (see **bridge, Wheatstone**) adapted to the measurement of the difference between two nearly equal resistances, with the elimination of errors due to the connections. The bridge is of the slide-wire type (the ordinary 4-gap form is easily adapted to the purpose); the resistance ρ of the slide wire per unit length being accurately known. X and S are to be compared (See figure.)

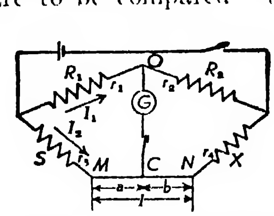


Diagram of Carey-Foster bridge circuit

A balance is first secured with the contact C at a distance a_1 from M. Then X and S are interchanged, and another balance obtained with C at distance a_2 from M. It may then be shown that

$$X - S = (a_1 - a_2)\rho.$$

The Callendar and Griffiths bridge is a special type of Carey-Foster bridge used with **resistance thermometers.** (See also **bridge, Heydweiller.**)

BRIDGE, ELECTRICAL. The electrical bridge is a term referring to any one of a variety of electric networks, one branch of which, the "bridge" proper, connects two points of equal potential and hence carries no current when the circuit is properly adjusted or "balanced." This is well illustrated by the **Wheatstone bridge** and the **Carey-Foster bridge** for measuring **resistances.** Among many other important special types may be mentioned the following: the decade bridge, of the Wheatstone type, in which the ratio coils are decimal multiples of an ohm; the percentage bridge, in which a change of one division on the slide-wire scale corresponds to a change of 1% in the ratio of the compared resistances; the **Callendar and Griffiths bridge,** a special adaptation of the Carey-Foster type; the **Thomson (Kelvin) double bridge,** having eight arms and used for comparing low-resistance standards; the **Wien bridge** for a-c capacities, the **Nernst high-frequency capacitance bridge,** and the farad bridge which reads capacitances directly in farads: the inductance bridge and the Heaviside mutual inductance bridge; the **resonance** and the **Maxwell bridges** for comparison of inductance with capacitance; and the frequency bridge, resembling the Wheatstone bridge but used for the measurement of alternating current frequencies.

BRIDGES, FERGUSON CLASSIFICATION OF. Most special bridge circuits for measuring resistance, capacitance, inductance, or frequency are special cases of the four-arm (Wheatstone) bridge with complex impedances in the branches. It is desirable that the bridge be balanced by adjustments on only two elements, and that the effects of these adjustments be independent. The equations for balance may contain the impedances of the (two) fixed branches as a ratio (ratio-arm bridges) or as a product (product-arm bridges). These two categories can be subdivided according to whether the ratio (or

product) is pure-real or pure-imaginary at balance.

BRIDGE, FREQUENCY. Any **bridge** in which the balance depends on frequency may be used to measure frequency. The Wien bridge (see **bridge, Wien**) is commonly used for this purpose.

BRIDGE, HAY. A modified Maxwell-Wien bridge (see **bridge, Maxwell-Wien**) suitable for measuring high-Q inductors.

BRIDGE, HEAVISIDE. A bridge designed to measure **mutual inductance,** which is similar to the **Wheatstone bridge.**

BRIDGE, HEAVISIDE-CAMPBELL. A **bridge** designed for the comparison of **self-** and **mutual inductances.**

BRIDGE, INDUCTIVE-RATIO. A four-arm **bridge** in which the two adjacent fixed arms are closely-coupled inductors.

BRIDGE, HEYDWEILLER (ALSO CALLED CAREY-FOSTER BRIDGE). A **bridge** for the comparison of capacitance with mutual inductance.

BRIDGE, HOOPES CONDUCTIVITY. A modification of the Kelvin double bridge (see **bridge, Kelvin double**) designed for the rapid determination of the conductivity of wire samples.

BRIDGE, KELVIN. A double bridge for the measurement of very low resistances.

BRIDGE, KELVIN DOUBLE. An arrangement for measuring four-terminal resistors independently of lead and contact resistance.

BRIDGE MAGNETIC AMPLIFIER. See **magnetic amplifier, bridge.**

BRIDGE, MAXWELL M ~ L. A **bridge** for the comparison of a **mutual inductance** with the **self-inductance** of one of the coils.

BRIDGE, MAXWELL-WIEN. A bridge for measuring inductance in terms of capacitance.

BRIDGE, MUELLER. A bridge for measuring four terminal resistors, particular resistance thermometers.

BRIDGE, MUTUAL INDUCTANCE. A modified Maxwell Wien bridge (see **bridge, Maxwell-Wien)** for measuring **mutual inductance** in terms of resistance and capacitance.

BRIDGE, OWEN. A bridge for the determination of inductance in terms of capacitance and resistance, with the advantage of being useful, over a very wide range of inductance, with reasonable-size capacitors.

BRIDGE RECTIFIER. A full-wave rectifier circuit arranged as shown.

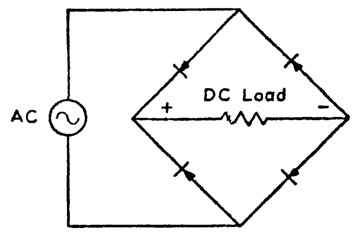


Diagram of full-wave rectifier circuit

BRIDGE, SCHERING. A bridge designed for the measurement of capacitance and dielectric loss. It is particularly useful for precision measurements on capacitors at low voltage, and for the study of insulation at high voltage.

BRIDGE, SLIDE-WIRE. See **bridge, Wheatstone.**

BRIDGE, STROUD AND OATES. The conjugate of the Anderson bridge (see **bridge, Anderson**) obtained by interchanging the detector and voltage supply.

BRIDGE, WAGNER EARTH (GROUND). An addition to almost any a-c bridge to prevent errors, due to stray capacitance, in measuring high impedances. The addition consists of a **potentiometer** connected across the **oscillator,** with the movable tap grounded. It may also be necessary at high frequencies to shunt the potentiometer with a double-stator capacitor.

BRIDGE, WHEATSTONE. One of the simplest and best-known **bridge** networks for measuring electrical **resistances.** Referring to Fig. 1, let R_1 be the unknown resistance and R_2 a known resistance, preferably not

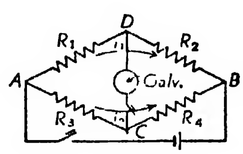


Fig. 1

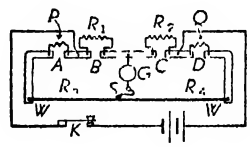


Fig. 2

Sketches of simple and four-gap Wheatstone bridge circuits

very different from R_1, in terms of which R_1 is to be measured. R_3 and R_4, called the ratio arms, are two other resistances which may be varied continuously or by very small stages and the values of which are known, either in ohms or relatively to each other. From C to D is the bridge proper, containing a **galvanometer.** To measure R_1, the resistances R_3 and R_4 are adjusted until the galvanometer shows no current, which means that C and D are at the same potential. It then readily follows from the **law of potential drop** that $R_1:R_2 = R_3:R_4$, and hence $R_1 = R_2R_3/R_4$. Fig. 2 shows a "slide-wire" form having a graduated resistance wire and four gaps. The **Carey-Foster bridge** is a special type of Wheatstone bridge.

BRIDGE, WIEN. See **Wien bridge-circuit.**

BRIDGED-T NETWORK. See **network, bridged-T.**

BRIDGING. The **shunting** of one electrical circuit by another.

BRIDGING GAIN. The ratio of the power a **transducer** delivers to a specified load impedance under specified operating conditions, to the power dissipated in the reference impedance across which the input of the transducer is bridged. If the input and/or output power consist of more than one component, such as multifrequency signal or noise, then the particular components used and their weighting must be specified. This gain is usually expressed in decibels.

BRIDGING LOSS. The ratio of the power dissipated in the reference impedance across which the input of a **transducer** is bridged, to the power the transducer delivers to a specified load impedance under specified operating conditions. If the input and/or output power consist of more than one component, such as multifrequency signal or noise, then the particular components used and their weighting must be specified. This loss is usually expressed in decibels. In telephone practice this term is synonymous with the **insertion loss** resulting from bridging an impedance across a circuit.

BRIGHTNESS. The attribute of visual perception in accordance with which an area appears to emit more or less light. **Luminance** is recommended for the photometric quantity, which has been called "brightness." Luminance is a purely photometric quantity. Use of this name permits "brightness" to be used entirely with reference to the sensory response. The photometric quantity has been often confused with the sensation merely because of the use of one name for two distinct ideas. Brightness is the term to be used, properly, in nonquantitative statements, especially with reference to sensations and perceptions of light. Thus, it is correct to refer to a brightness match, even in the field of a **photometer,** because the sensations are matched and only by inference are the photometric quantities (luminances) equal. Likewise, a photometer in which such matches are made should properly be called an "equality-of-brightness" photometer. A photoelectric instrument, calibrated in foot-lamberts, should not be called a "brightness meter." If correctly calibrated, it is a "luminance meter." A troublesome paradox is eliminated by the accepted distinction of nomenclature. The luminance of a surface may be doubled, yet it now is permissible to say that the brightness is not doubled, since the sensation which is called "brightness" is generally judged to be not doubled.

BRIGHTNESS CHANNEL. The use of this term should be avoided. (See **monochrome channel; luminance channel.**)

BRIGHTNESS CONTROL. The manual bias control of a **cathode-ray tube.** The brightness control affects both the **average brightness** and the **contrast** of the picture.

BRIGHTNESS SIGNAL. See **monochrome signal.**

BRILLIANCE. Brilliance is that attribute of any **color** in respect of which it may be classed as equivalent to some member of a series of greys ranging between black and white. Yellow is the most brilliant color in the spectrum of white light.

BRILLOUIN EFFECT. Upon the scattering of monochromatic radiation by certain liquids, a doublet is produced, in which the frequency of each of the two lines differs from the frequency of the original line by the same amount, one line having a higher frequency, and the other a lower frequency.

BRILLOUIN FUNCTION. In the **quantum theory** of **paramagnetism,** a quantum-mechanical analog of the Langevin equation

(see **Weiss theory; Langevin formula**) was developed by Brillouin, with the following result:

$$\frac{I_s}{I_0} = \frac{2J+1}{2J} \operatorname{ctnh} \frac{(2J+1)a}{2J} - \frac{1}{2J} \operatorname{ctnh} a/2J$$

where $a = Jg\beta(H + NI_s)/kT$, β is the Bohr magneton, $eh/4\pi mc$, J is the momentum quantum number, and

$$g = \frac{2mc}{e} = \frac{\text{magnetic moment}}{\text{angular momentum}};$$

(g is 1 for orbital motion alone; 2, when the moment is due entirely to spin).

BRILLOUIN ZONE. In the **band theory of solids** the various electronic states belonging to a band may be classified according to their **wave vectors.** If these vectors are taken to be position vectors in "**k-space**" it is found that they all lie inside a certain polyhedron Such a polyhedron is called a Brillouin zone. and can often be constructed merely from consideration of the crystal lattice and its symmetry. In the study of complex metals and alloys, where there may be several overlapping bands, the geometry of the zones plays an important role.

BRITISH THERMAL UNIT. Unit of work or energy, abbreviated BTU. The energy required to raise the temperature of one pound of water through a temperature rise of one degree Fahrenheit without any vaporization. When greater precision is needed, the temperature rise is specified as from 39°F to 40°F.

BROADSIDE ARRAY. See **antenna array, broadside.**

BROMINE. Non-metallic liquid element. Symbol Br. Atomic number 35.

BROMWICH CONTOUR. An integration path, used in the **calculus of residues.** It extends from $c - i\infty$ to $c + i\infty$, where c is real and positive and the path is so chosen that all **singularities** of the complex function are to the left of it.

BRONSON RESISTANCE. The resistance formed by two electrodes in a gas which is exposed to a constant ionization source.

BROOKES DEFLECTION POTENTIOMETER. See **potentiometer, Brookes deflection.**

BROOKES POTENTIOMETER. See **potentiometer, standard-cell comparator.**

BROWN CONVERTER. A **relay** designed to operate as a voltage-operated switch in a contact-modulated amplifier. (See **amplifier, contact-modulated.**)

BROWN RECORDER. A recording instrument which records the voltage applied to its input on a moving tape. The instrument is of the potentiometer type, and is much used with infrared spectrometers. It is made by the Brown Instrument Division of the Minneapolis-Honeywell Corp.

BROWNIAN MOVEMENT. The irregular and random movement of small particles suspended in a fluid, discovered by Robert Brown in 1827, and now known to be a consequence of the thermal motion of fluid molecules. The motion is caused by statistical fluctuations of pressure over the surface of the particle and the distribution of particle velocity is similar to that of a gas molecule of the same weight as the particle.

BRUSH. A device for conducting current to or from a rotating part The brush is stationary, and is held and guided by a fixed brush holder in which it slides freely. There may be several brushes side by side to form a single-brush set. The rotating member may be the **commutator** of a d-c **generator** or **motor,** or it may be the slip **rings** of an a-c motor or generator. Other examples of brushes are those used in **magnetos** and static electricity machines.

BRUSH DISCHARGE. See **ionized gases.**

BUBBLE CHAMBER. A vessel filled with a transparent liquid so highly superheated that an ionizing particle moving through it starts violent boiling by initiating the growth of a string of bubbles along its path. Its applications are similar to those of a **cloud chamber.**

BUBBLE GAUGE. A small liquid-containing trap, installed in a gas line, which permits the rate of gas flow to be determined by counting the number of gas bubbles, as they move through the liquid.

BUBBLE OVERVOLTAGE. See **overvoltage, bubble.**

BUBBLE RAFT. An elegant means for visual demonstration of the properties of **dislocations** in metals. A raft of bubbles floating on soap solution takes a structure that may be described as a two-dimensional crystal, and when deformed it is observed that **slip** takes place by the propagation of dislocations.

BUBBLE PRESSURE. The pressure within a bubble of gas in liquid is greater than the pressure in the surrounding liquid by $2\gamma/R$ where γ is the **surface tension** and R is the bubble radius. If, as in a soap bubble, a bubble of gas is separated from the surrounding gas by a thin film of liquid, the pressure difference is twice this value.

BUCKING COIL. A coil so connected to provide a demagnetizing effect on another coil. An example is the hum-bucking coil in an electromagnetic loudspeaker where power supply pulsations are bucked out by the bucking coil.

BUCKLEY GAUGE. An extremely sensitive pressure gauge, based on measurement of the amount of ionization produced in the gas by a specified current.

BUCKLEY METHOD FOR OBTAINING INTERFERENCE PATTERNS WITH HIGHLY-CONVERGENT LIGHT. In this arrangement, light from a projection lantern falls upon a Polaroid plate or film (the polarizer) and is then strongly converged by a lens system such as the **Abbe condenser.** The third element of apparatus in the train is a doubly-refracting crystal, and then the only additional apparatus necessary is a second piece of Polaroid (the analyzer), followed by a screen. A good-size image of the interference pattern appears on the screen.

BUCKLING. A measure of the curvature of the **neutron density distribution.** In a bare homogeneous reactor, the geometric buckling is that curvature needed for the reactor to be **critical,** as determined from its geometrical configuration, whereas the material buckling is the curvature obtainable in that material.

BUCKLING, GEOMETRIC. In **reactor** theory, the lowest **eigenvalue** that results from solving the wave equation

$$\nabla^2\phi(F) + B_g{}^2\phi(r) = 0$$

with the boundary condition that the thermal neutron flux, $\phi(r) = 0$ at the (extrapolated) boundary of the system. The geometric buckling $B_g{}^2$ is a property only of the geometry, i.e., the size and shape, of the system.

BUCKLING, MATERIAL. An obsolescent term for B^2 (or $B_m{}^2$ in conformity with $B_g{}^2$ in the foregoing equation) which is dependent only upon the material and composition of the medium However, the geometric buckling, $B_g{}^2$, of the critical system of a specified shape is equal to the material buckling, $B_m{}^2$, of the given multiplying medium.

BUDAN THEOREM. Used in locating the real roots of a **polynomial equation.** Let $P(x) = 0$ be the polynomial of degree n with real coefficients. Let a and b be real numbers, neither of which is a root of $P(x) = 0$, and suppose that $a < b$. Let V_a denote the number of variations of sign of

$$P(x),\ P'(x),\ P''(x),\ \cdots,\ P^{(n)}(x)$$

for $x = a$, after vanishing terms have been deleted, and similarly V_b the number of variations for $x = b$. Then $V_a - V_b$ is either the number of real roots of $P(x) = 0$ between a and b or exceeds the number of these roots by a positive even integer. A root of multiplicity m is here counted as m roots.

BUDDE EFFECT. The increase in volume of halogens, especially chlorine and bromine vapor, on exposure to light. It is a thermal effect, due to the heat from recombination of atoms.

BUFFER. A substance that enables a system or entity to resist changes in conditions, mechanical shocks, addition of foreign substances, etc Examples are: (1) An isolating circuit used to avoid reaction of a driven circuit upon the corresponding driving circuit. (2) A circuit having an output and a multiplicity of inputs so designed that the output is energized whenever one or more inputs are energized. Thus, a buffer performs the circuit function which is equivalent to the logical "or." (3) In physical chemistry, a buffer is a substance which, upon addition to a system, renders the hydrogen ion concentration resistant to, or less sensitive to, additions of acidic or alkaline substances (see **buffer solution**). There are other chemical

buffers, however, such as the oxidation-reduction buffer, which tends, in the same way, to stabilize the oxidation-reduction potential of a system.

BUFFER AMPLIFIER. See **amplifier, buffer.**

BUFFER SOLUTION. A solution whose **pH** is changed only a relatively small amount by the addition, within limits, of acids and bases—even strong ones if the amount added is small. Solutions of weak acids or bases or their salts, such as phosphates, borates, etc., are buffer solutions.

BUG. Colloquialism for a code-transmitting key which is semiautomatic in its operation. Lever movement in one direction causes a single dash, while movement in the opposite direction activates a spring contact that sends a series of equally-spaced dots.

BUILDING-OUT SECTION. A **stub** used for tuning or matching purposes.

BUILDING-UP PRINCIPLE. The postulate that the totality of the electronic terms of an atom or molecule can be obtained by successive bringing together of the parts. In an atom this building-up may be accomplished only in one way, i.e., by adding the electrons successively to the nucleus, considering their successive orbital arrangements. In a molecule, this method may also be used, or otherwise methods may be elaborated for bringing together (from infinite separation) the whole atoms that make up the molecule, or for parting (from zero nuclear separation) the hypothetical united atom. (See **atom, united.**)

BULK MODULUS (OR MODULUS OF VOLUME ELASTICITY). The application of pressure to a material medium changes its volume. The bulk modulus for an **elastic medium** is defined as

$$B = -\frac{\Delta p}{\Delta V/V_0}$$

where Δp is the increase in pressure, ΔV is the decrease in volume, and V_0 is the original volume. The modulus may be defined and measured under **adiabatic, isothermal** or other specified conditions.

"BUNCHER" GAP. In a velocity-modulation electron tube the pair of electrodes which causes the beam to become modulated. The "buncher" gap is more frequently called simply the input gap.

BUNCHING, IDEAL. See **ideal bunching.**

BUNCHING PARAMETER. A parameter which determines the degree of bunching and the waveform of the density-modulated beam in a **klystron.**

BUNSEN COEFFICIENT. (Absorption coefficient.) The volume of gas under **standard conditions** of temperature and pressure (S.T.P.) which is absorbed by a unit volume of gas solution.

BUNSEN ICE CALORIMETER METHOD FOR LATENT HEAT OF FUSION. A vessel containing some ice and water, but no air, is sealed by a mercury column. Addition of a known amount of heat (a measured amount of water at known temperature) will melt ice, and the increase in volume of the water-ice mixture is registered by the mercury column.

BUNSEN SCREEN. A **photometer** screen consisting of a diaphragm of paper or parchment with a translucent central spot of oil or paraffin.

BUOYANCY. The apparent loss of weight by a solid body immersed wholly or partially in a fluid. The total buoyancy force is equal to the weight of the displaced fluid and acts through the position of the center of gravity of the displaced fluid.

BUOYANCY METHOD FOR GAS DENSITY. A very sensitive balance supports a large bulb of known external volume inside a gas-tight case. The beam is balanced with the case evacuated or filled with a standard gas, and then with the gas to be investigated. The gas density can then be calculated from the upthrusts, using **Archimedes principle.**

"BUPS" ANTENNA. See **antenna, "Bups."**

BURGER - DORGELO - ORNSTEIN SUM RULE FOR ATOMIC SPECTRA. The sum of the intensities of all the lines of a multiplet which belong to the same initial or final state is proportional to $2J + 1$, the statistical weight of the same initial or final state, respectively.

BURGERS DISLOCATION. See **screw dislocation.**

BURGERS VECTOR. A vector representing the displacement of the material of the lattice required to create a **dislocation.** As usually defined, the Burgers vector must always be a **translation vector** of the lattice.

BURST. (1) In **cosmic ray** studies, an exceptionally large electric **pulse** observed in an **ionization chamber,** signifying the simultaneous arrival or emission of several or many ionizing particles. Such an event may be caused by a cosmic-ray shower or by a **spallation** disintegration of the type that can produce a star. (2) In communications, a sudden increase in signal strength of waves being received by **ionospheric reflection.** The effect is believed to be caused by a disturbance of the ionosphere by meteors.

BURST PEDESTAL (COLOR-BURST PEDESTAL). The rectangular, pulse-like component which may be part of the **color burst.** The amplitude of the color-burst pedestal is measured from the a-c axis of the sine-wave portion to the **horizontal pedestal.**

BUS. (1) In electrical devices, any rigid conductor used to distribute current to several branches. (2) In computer work, one or more conductors which are used as a path for transmitting information from any of several sources to any of several destinations.

BUTTERFLY CIRCUIT. See **resonator, butterfly.**

BUTTON. The container of carbon granules in a carbon microphone. (See **microphone, carbon.**)

BUYS BALLOT LAW. Professor Buys Ballot at Utrecht in 1857 stated this law: "Standing with back to wind, low pressure is to left and high pressure to right in northern hemisphere, with the reverse being true in the southern hemisphere." This law was one of the earliest statements of the principles of winds now accepted as common meteorological knowledge.

BYPASS CAPACITOR. A capacitor used to provide a comparatively-low, shunting impedance for currents at some point in a circuit.

BYPASS MIXED HIGHS. The **mixed-highs signal** that is shunted around the color-subcarrier modulator or demodulator.

BYPASS MONOCHROME SIGNAL. A **monochrome signal** that is shunted around the color-subcarrier modulator or demodulator.

C

C. (1) Capacitance or permittance or designation for capacitor (C). (2) Partial capacitance (c). (3) Third Cauchy constant (C). (4) Compliance (C). (5) Sound conductivity of an opening (c). (6) Concentration of solution (c or C). (7) Element carbon (C). (8) Velocity of light in vacuum (c). (9) Degree Centigrade (celsius preferred) (°C). (10) Normality of solution (C). (11) Heat capacity, total (C), per unit mass (which is specific heat) (c), heat capacity per mole (c, C or C_M), heat capacity per atom or molecule (c or C_m), specific heat at constant volume (c_v), specific heat at constant pressure (c_p), molar heat at constant volume (C_v), molar heat at constant pressure (C_p). (12) Thermal conductance (C). (13) Planck radiation law constants (c_1, c_2). (14) Induction coefficient (c). (15) Sutherland constant (C). (16) Designation for d-c voltage sources for vacuum tubes (C). (17) Coulomb (Cb). (18) Complex, as used in narrow fine structure, isotopic or nuclear spin hyperfine structure (c).

C BATTERY. A battery used to supply bias. (See **bias.**)

C-BIAS. See **bias.**

C CORE. A spirally-wound magnetic core which is formed to a desired rectangular shape before it is cut into two c-shaped pieces. In this form it may be placed around a **transformer** or **magnetic amplifier** coil as a superior replacement for the more conventional E-I lamination. Its principal advantages lie in the fact that grain-oriented materials may be used, the **effective air gap** may be made quite small, and assembly time is reduced.

C-LINE. Fraunhofer line at 6562.8 Å caused by hydrogen in the atmosphere of the sun.

"C" NEUTRONS. Neutrons of such energy that they are strongly absorbable in cadmium. "C" neutrons have energies from zero up to about [illegible] ev.

C-NUMBER THEORY. A classical field theory, i.e., a field theory in which wave functions are (in general complex) functions of position and time. (Cf. **q-number theory.**)

"C RING." See **magnetron, tuneable, methods of tuning.**

C SUPPLY. The supply for the **C voltages** for a vacuum tube.

CABLE. A **transmission line** or group of transmission lines mechanically assembled in compact flexible form.

CADMIUM. Metallic element. Symbol Cd. Atomic number 48.

CADMIUM CELL. A standard or "normal" cell usually constructed in the "H" form. The cathode is an amalgam of $12\frac{1}{2}$ parts of cadmium and $87\frac{1}{2}$ parts of mercury by weight. The anode may be made of highly purified mercury or of amalgamated platinum. The electrolyte is a saturated solution of cadmium sulfate in water. The cathode is surrounded by undissolved cadmium sulfate crystals, and the anode is covered with a paste made of mercurous sulfate and cadmium sulfate solution. The cell is sealed to prevent evaporation. At the ordinary temperature (20°) the cadmium cell furnishes an electromotive force of 1.018636 volts, and this varies only 0.00004 volt per degree change of temperature.

CADMIUM CUT-OFF. The neutron absorption **cross-section** of cadmium is high for neutron energies below about 0.3 ev, but drops sharply at higher energies. This makes cadmium a selective absorber of slow neutrons. (See **cadmium ratio.**)

CADMIUM RATIO. The ratio of the neutron-induced saturated activity in an unshielded foil to the saturated activity of the same foil when it is covered with cadmium. It is a measure of the relative numbers of neutrons of thermal energies and those of higher energy.

CADMIUM RED LINE. A line in the spectrum of cadmium at 6438.4696 angstroms which, because it was the most narrow line known to Michelson, was used by him in measuring the standard meter and has been accepted as the primary standard of wavelengths. It is now being superseded by lines from the spectrum of mercury-198, particularly a green line at 5460.7532. (See **mercury-198** and **international angstrom.**)

CAGE ANTENNA. See **antenna, cage.**

CAILLETET AND MATHIAS, LAW OF. Also called the law of the rectilinear diameter. The mean value of the densities of a substance in the saturated vapor state and in the liquid state, at the same temperature, is a linear function of the temperature.

CALCITE. A natural hexagonal crystal of calcium carbonate. It cleaves readily into rhombohedrons. Because it is readily available and because of its optical properties, particularly with respect to polarization of light, it has been much used in connection with the study of polarized light. (See **Nicol Prism.**) Calcite is also called **Iceland spar.**

CALCITE GRATING SPACE. In the Siegbahn System:

Effective	18°C	3.02904×10^{-8} cm
True	20°C	3.02951×10^{-8} cm

In the cgs System

True	20°C	3.03567×10^{-8} cm

The distance between diffracting surfaces in calcite crystals used in x-ray diffraction.

CALCIUM. Metallic element. Symbol Ca. Atomic number 20.

CALCULATOR, NETWORK. A layout of inductance, capacitance and resistance units, and generators used for duplicating the electrical characteristics of a power system so that various system conditions may be studied.

CALCULUS, DIFFERENTIAL AND INTEGRAL. A branch of mathematics dealing with the rate of change of a function and with the inverse process.

CALCULUS OF FINITE DIFFERENCES. Study of the properties of **differences,** particularly as applied to **interpolation** procedures.

CALCULUS OF RESIDUES. The study of the **Cauchy integral** and **theorem,** especially for evaluation of integrals in the complex plane. The fundamental theorem of the subject is: if $f(z)$ is **analytic** within a region C, except for a finite number of **poles,** the value of the contour integral $\int_C f(z)dz = 2\pi i\Sigma$, where Σ is the sum of the **residues** of the function at the poles within the region C.

CALCULUS OF VARIATIONS. Study of maximum and minimum properties of definite integrals. A simple case is

$$I = \int_a^b f(x,y,y')dx$$

where $y(x)$ is to be determined so that the integral is either a maximum or a minimum. In either case, y is said to be an **extremal** and the integral has a stationary value. See **brachistochrone, Euler equation, isoperimetric equation.**

CALEOMETER. An electrical instrument used to measure the heat loss from a calibrated wire and useful in making a number of determinations, such as that of the variation of the concentration of one of the components of the gas surrounding the wire.

CALIFORNIUM. Transuranic element. Symbol Cf. Atomic number 98.

CALLENDAR AND BARNES METHOD FOR MECHANICAL EQUIVALENT OF HEAT. A steady flow of water through a thermally-insulated tube is heated by a steady electric current, and a temperature difference is set up at the ends of the tube. Except for the measurement of electric power, the evaluation of the result is similar to that in mechanical, continuous-flow methods.

CALLENDAR AND GRIFFITHS BRIDGE. See **bridge, Callendar and Griffiths.**

CALLIER COEFFICIENT. The density of photographic negatives measured by parallel light is greater than if measured by diffused light. This effect is caused by scattering. Callier defined a coefficient as

$$Q = \frac{\text{density measured by parallel light}}{\text{density measured by diffused light}}.$$

The average value of Q is about 1.4 ± 0.2.

CALMS OF CANCER. The belts of high pressure lying north of the northeast **trade winds.** (See **atmosphere, circulation of the.**)

CALMS OF CAPRICORN. The belts of high pressure lying south of the southeast **trade winds.** (See **atmosphere, circulation of the.**)

CALOMEL ELECTRODE. See **electrode, normal calomel.**

CALORESCENCE. The production of visible light by means of energy derived from invisible **radiation** of frequencies below the visible range. Tyndall found it possible to raise a piece of blackened platinum foil to a red heat by focusing upon it infra-red radiation from an arc or from the sun, the visible wavelengths having been filtered out. It is to be noted that the transformation is indirect, the light being produced by heat and not by any direct stepping-up of the infra-red frequency.

CALORIE. A unit for the measurement of the quantity of heat. As originally defined, it was the amount of heat required to raise the temperature of one gram of water through one degree Centigrade. As thermal measurements increased in precision, this definition was not sufficiently exact and many different kinds of calories were used, considerable confusion resulting. After 1930 an artificial, conventional calorie was defined by the relation 1 calorie = 4.1833 international joules and, in 1948, it was redefined as 1 calorie = 4.1840 absolute joules. This definition is now generally accepted in the United States. The large calorie (Cal. or Kcal.) is 1,000 times as large. Another artificial calorie, used in engineering steam tables, is the International Table calorie: 1 I.T. calorie = $\frac{1}{860}$ international watt-hour = 0.00116298 absolute watt-hour.

Conversion to other energy units gives:

1 cal. = 0.00396573 B.T.U.
1 cal. = 0.0412917 liter-atmosphere
1 cal. = 0.999346 I.T. cal.

CALORIFIC INTENSITY. The maximum temperature attainable by combustion of a given fuel with atmospheric oxygen under atmospheric pressure.

CALORIFIC VALUE. The number of units of heat obtained by complete combustion of unit mass of a substance. Determinations of calorific value are very commonly made in the evaluation of fuels, the study of foods, etc.

CALORIFIC VALUE, GROSS. The quantity of heat produced by the combustion of a unit mass of a substance with oxygen under pressure, as in a bomb calorimeter. If this value is corrected for the **latent heat of evaporation** of the water present, then the net calorific value is obtained.

CALORIMETER. An apparatus for measuring the change of **heat content** of a system.

CALORIMETER, ADIABATIC. A **calorimeter** so well insulated from its surroundings that reactions or processes involving heat transfer can be studied without having any appreciable heat exchange occurring with the outside.

CALORIMETER, DIFFERENTIAL. A device for measuring a quantity of heat by comparing it with a known quantity of heat at the same temperature.

CALORIMETER, GAS. An apparatus used in the analysis of combustible gases, primarily to determine calorific value and, incidentally, to determine moisture content and to test for the presence of other materials.

CALORIMETER, NERNST. A **calorimeter** in which a substance whose **specific heat** is to be measured is suspended in a glass or metal envelope which can be evacuated. The method is particularly suited for work at low temperatures. The envelope is immersed into a vessel containing the cooling agent, and the substance is cooled by admitting a small amount of gas into the envelope. The substance is then thermally insulated by evacuating the envelope, and the specific heat is measured by recording the increase in temperature caused by supplying a known amount of heat In Nernst's original experiment the same wire, attached to the substance, served as heater and resistance thermometer.

CALORIMETER, OXYGEN-BOMB. A calorimeter in which a weighed sample of solid or liquid material is ignited by an electrically-heated wire and burned by oxygen under pressure. The heat evolved is determined, usually by absorption in a water

jacket (see **calorimeter, water**) surrounding the combustion chamber (oxygen-bomb).

CALORIMETER, SIMON AND LANGE VACUUM. An improvement of Nernst's vacuum calorimeter (see **calorimeter, Nernst**) in which the substance inside the vacuum envelope is surrounded by a shield to which a small container with the cooling agent (liquid air, liquid hydrogen or liquid helium) is attached. By pumping off the vapor from the container, a lower starting temperature can be obtained than by pumping off the vapor of the large bath of cooling agent surrounding the vacuum envelope. Moreover, by regulating the pressure in the container, the temperature difference between the substance and the shield can be kept small

CALORIMETER, SODIUM PEROXIDE. A **calorimeter** in which a weighed sample of solid or liquid is burned by oxygen derived from sodium peroxide, usually when an accelerator such as potassium perchlorate or benzoic acid is added to aid combustion.

CALORIMETER, WATER. A thermally-insulated metal cup containing water and furnished with a thermometer The quantity of heat to be measured is applied to the water, and the rise of temperature resulting multiplied by the mass of the water, gives the number of calories received. Corrections must of course be made for the heat absorbed by the cup, thermometer, and other accessories, the "water equivalent" of which is in the computation simply added to the mass of actual water. Allowance must also be made for heat lost or unintentionally introduced through radiation and conduction; for which purpose the **Newton law of cooling** is commonly used.

CALORIMETRIC COEFFICIENT. One of the following six coefficients, used to express the rate of absorption of heat during reversible changes of pressure, volume, and temperature:

(1) Heat of compression at constant volume, $(\partial q/\partial p)_v$.
(2) Heat of expansion at constant pressure, $(\partial q/\partial v)_p$.
(3) Specific heat at constant volume, $(\partial q/\partial T)_v$.
(4) Specific heat at constant pressure, $(\partial q/\partial T)_p$.
(5) Latent heat of change of pressure, $(\partial q/\partial p)_T$.
(6) Latent heat of change of volume, $(\partial q/\partial v)_T$.

In these expressions, q is the quantity of heat, p, the pressure, v, the volume and T, the absolute temperature.

CALORIMETRY. The quantitative determination of **heat content.**

CALUTRON. A production isotope separator of the electromagnetic type based on the 180° focussing Dempster **mass spectrograph.**

CAMERA LENSES. Great effort has been put into the design of camera lenses and each manufacturer has designs and names of his own However most modern camera lenses are elaborations of the "Cooke Triplet" which consists of a negative lens spaced unsymmetrically between two positive lenses. The famous "Tessar" lens is a Cooke triplet in which the rear crown lens is replaced by a doublet. The Hector series replaces each of the three lenses of the Cooke triplet with a doublet.

CAMERA SPECTRAL CHARACTERISTIC. In television, the sensitivity of each of the camera color-separation channels with respect to wavelength It is necessary to state the camera terminals at which the characteristics apply Because of nonlinearity, the spectral characteristics of some kinds of cameras depend upon the magnitude of **radiance** used in their measurement. Nonlinearizing and matrixing operations may be performed within the camera.

CAMERA TAKING CHARACTERISTIC. The use of this term should be avoided. (See **camera spectral characteristic.**)

CAMERA TUBE. See **tube, camera.**

CAMPBELL BRIDGE. See **bridge, Campbell.**

CAMPBELL-COLPITTS BRIDGE. See **bridge, Campbell-Colpitts.**

CAMPBELL-LARSEN POTENTIOMETER. See **potentiometer, Campbell-Larsen.**

CAMPBELL METHOD. A method of measuring low pressures, in the range 10^{-1} to 10^{-3} mm Hg. A lamp filament constitutes one arm of a Wheatstone bridge, the other

arms consisting of resistances so chosen that the bridge is balanced when the filament temperature is about 100°C. The balance is achieved by adjusting the voltage across the bridge, when the pressure is so low that heat conduction by the residual gas plays no appreciable role (10^{-4} mm or less). The change in voltage required to re-balance the bridge when a measurement is being made is then a measure of the gas pressure. (See **Pirini gauge; manometer, hot wire.**)

CANADA BALSAM. The turpentine yielded by the balsam fir. It is a yellowish, viscid liquid solidifying to a transparent mass. It is much used as a transparent cement for cementing together compound lenses. Now being replaced by certain methacrylate plastics.

CANAL RAYS. This term is a bad translation of the German *Kanalstrahlen.* A more accurate designation would be "tunnel rays" or "perforation rays." They consist of positive particles in a **vacuum tube** which escape through tunnels or holes bored in the cathode. Positive ions originating in the gas near the **cathode** move toward it with great speed, ordinarily striking it and causing the surface disintegration and **sputtering** of the metal soon observable; also doubtless releasing **cathode-ray** electrons. But if the cathode is perforated with holes so placed that the positive rays can enter them, some of the particles pass through into the space behind the cathode. In especially constructed canal-ray tubes, this space is elongated so that the positive rays, now isolated from the cathode rays, can be studied separately.

CANDELA. Unit of **luminous intensity:** it is of such a value that the luminous intensity of a full radiator at the freezing point of platinum is 60 units of luminous intensity per cm^2. (See also **candle.**)

CANDLE. Unit of **luminous intensity.** One candle is defined as the luminous intensity of $\frac{1}{60}$ square centimeter of a **blackbody** radiator operating at the temperature of solidification of platinum. Values for standards having other **spectral distributions** are derived by the use of accepted luminosity factors. One candle produces one lumen of luminous flux (see **flux, luminous**) through an area subtending a solid angle of one steradian measured from the source.

CANDLE POWER. In the earlier days of **photometry, luminous intensity** was measured by rating a source in terms of ordinary candles. The need for greater precision and reproducibility led to, first, specification of the materials and dimensions of the candle or lamp, and more recently to the definition of the standard candle in terms of the luminous intensity of a blackbody radiator at the temperature of solidification of platium. (See **candle.**)

CANDLE POWER, APPARENT. See **apparent candle power.**

CANDLE POWER, BEAM. See **beam candle power.**

CANONICAL. Used to describe a standard form of a function or equation, especially when the form is simple. A canonical **matrix,** for example, has nonzero elements only on the main diagonal.

CANONICAL EQUATION OF MOTION. For the kth set of generalized coordinates and conjugate momenta in a conservative dynamical system, there can be written a pair of first-order partial differential equations:

$$\frac{\partial H}{\partial p_k} = \frac{dq_k}{dt}$$

$$\frac{\partial H}{\partial q_k} = -\frac{dp_k}{dt}$$

where H is the Hamiltonian function for the system and p_k and q_k are generalized momenta and coordinates, respectively. These equations are called the canonical equations of motion. (See also **Hamiltonian function; coordinates and momenta (generalized).**)

CANONICAL TRANSFORMATION. A transformation from one set of generalized **coordinates and momenta** to a new set such that the form of the **canonical equations of motion** is preserved. This usually involves finding a transformation function S which is a continuous and differentiable function of the old and new generalized coordinates and the time. The transformation can be defined by

$$L(q,\dot{q}) = L'(Q,\dot{Q}) + \frac{dS}{dt}$$

where L is the **Lagrangian function** in the original set of coordinates, and L' is the La-

grangian function in the transformed set of coordinates.

CAPACITANCE. (1) Ratio of the **electric charge** given a body to the resultant change of **potential.** It is usually expressed in **coulombs** of charge per volt of potential change, that is, in terms of the farad, or its submultiples; the c.g.s. electromagnetic unit is the abfarad. If a conductor is completely isolated, that is, far removed from other conductors, including the earth, and is surrounded by a homogeneous, perfectly insulating dielectric, its capacitance depends only upon the size and shape of its external surface, and upon the **dielectric constant** of the surrounding medium. Very long electric circuits, especially when the wire is surrounded by a conducting sheath, as an ocean cable, have considerable capacitance because of the condenser-like action of wire and sheath with the insulation between them acting as dielectric. The same is true of insulated wire wound in a close coil, adjacent turns of which, being at slightly different potential, act as the conductors of a condenser; an effect which may be partially avoided by a criss-cross or "honey-comb" winding or by a "banked" winding (in flat spirals). The capacitance of a circuit, whether thus "distributed" or intentionally introduced by means of capacitors, acts as a capacitor in parallel with the conductor, and may have marked effect upon alternating or variable currents traversing it

(2) Acoustic capacitance has been defined as the negative imaginary part of acoustic impedance. (For a usage of this character, see **capacitance, specific acoustic.**)

CAPACITANCE ALTIMETER. See **altimeter, capacitance.**

CAPACITANCE BRIDGE. See **bridge, capacitance.**

CAPACITANCE, COEFFICIENTS OF. The equations for charges on conductors in terms of coefficients of induction (see **induction, coefficients of**) can be rewritten in terms of potential differences as:

$$q_1 = C_{1\infty}V_1 + C_{12}(V_1 - V_2) + C_{13}(V_1 - V_3) + \cdots + C_{1n}(V_1 - V_n)$$

$$q_2 = C_{21}(V_2 - V_1) + C_{2\infty}V_2 + \cdots + C_{2n}(V_2 - V_n)$$

$$q_n = C_{n1}(V_n - V_1) + C_{n2}(V_n - V_2) + \cdots + C_{n\infty}V_n$$

These coefficients of capacitance are related to the coefficients of induction (see **induction, coefficients of**) as follows:

$$c_{mk} = -c_{mk}, \quad m \neq k$$

$$c_{m\infty} = c_{m1} + c_{m2} + \cdots + c_{mm} + \cdots + c_{mn}$$

CAPACITANCE, DISTRIBUTED. The capacitance which is inherent in any **coil** because of the adjacent turns, layers, windings, etc., which are separated by some dielectric material and which have voltage differences between them. The result of this is a capacitance action which lowers the effective **inductance** of the coil. This capacitance is often considered as lumped and in parallel with the true inductance of the coil (or other **arrangement** of conductors).

CAPACITANCE, EFFECTIVE. The total **capacitance** found between two points in a circuit.

CAPACITANCE, GEOMETRIC. The **capacitance** of an isolated conductor *in vacuo.* For a sphere of radius a,

$$V = \frac{Q}{a}, \quad \text{hence } C = Q/V = a.$$

where electrostatic units are used. For a hemisphere of radius a, $C = 0.845a$. For many other bodies C is approximated by $\sqrt{S/4\pi}$, where S is the surface area.

CAPACITANCE, OUTPUT (OF AN n-TERMINAL ELECTRON TUBE. The short-circuit **transfer capacitance** between the output terminal and all other terminals, except the input terminal, connected together.

CAPACITANCE, SPECIFIC ACOUSTIC. That coefficient which, when multiplied by 2π times the frequency, is the reciprocal negative imaginary part of the specific acoustic impedance (See **impedance, specific acoustic.**) The dimensions of specific acoustic capacitance are cm^5/dyne.

CAPACITANCE, STRAY. Undesired and unintentional **capacitance** between two bodies, such as the capacitance between **a** wire and a chassis in a piece of electronic equipment.

CAPACITIVE LOAD. An electrical load whose **reactance** component is negative, hence a load that acts like a combination of **resistance** and **capacitance.** (Cf. **inductive load.**) Capacitive loading may be the result of actual capacitors, or of virtual capacitors in the form of long transmission lines, or over-excited, synchronous, rotating equipment. Most a-c apparatus, such as motors, coils, etc., draw from the line a current which lags the voltage, and the use of some capacitive load is desirable in order to bring the total current and voltage more nearly in phase, and thus raise the **power factor.**

CAPACITIVE POST. See **post, capacitive.**

CAPACITOR (ELECTRICAL). An arrangement of conductors and **dielectrics** used to secure an appreciable capacitance, sometimes one of specified value. The essential feature of all capacitors is a system of two or more conductors, separated by layers of dielectric. The potential difference between the conductors, when charged, is limited by the electric polarization in the dielectric. This makes it possible to accumulate large charges at comparatively small voltages. The oldest form of capacitor is the **Leyden jar,** still often used where heavy electric discharges are desired. Many modern capacitors consist of alternate metal and dielectric plates or sheets, sometimes of metal foil and paraffin paper strips rolled in a compact bundle. Capacitors in which the dielectric is air, usually of adjustable capacitance, are much used in radio and other oscillatory circuits. An electrolytic capacitor consists of an electrolytic cell in which a current has deposited a very thin layer of nonconducting material on one of the electrodes. This layer acts as the capacitor dielectric. Such capacitors have very high capacitance in proportion to their size and weight, and are much used in electric **filters** and other electronic apparatus. Standard capacitors, of accurately known capacitance, are employed in electrical measurements. The capacitance depends upon the total area a and the thickness d of the dielectric and upon its dielectric constant k. If the dimensions are in centimeters, the capacitance for a capacitor of flat-plates is approximately given in electrostatic units by the formula $C = ka/4\pi d$ and in microfarads by $C = 8.84 \times 10^{-8} ka/d$. Thus, if there are 21 metal plates 10 cm sq, separated by 20 sheets of mica 0.01 cm thick and of dielectric constant 6, the capacitance is about 0.106 microfarads. The capacitance is often made adjustable by varying the distance d or by arranging the plates to move past one another so as to vary the area a of dielectric subject to the electric field between them. A capacitor is often called a condenser.

CAPACITOR ANTENNA. See **antenna, capacitor.**

CAPACITOR, BY-PASS. This is a **capacitor** placed in an electrical circuit to allow a-c to flow around some circuit component and cause d-c to flow through the component. The most common usage is in by-passing various voltage-dropping resistors used in vacuum-tube circuits to adjust the voltages applied to the several parts of the circuits. These resistors are by-passed so there will be no, or very little, alternating signal voltage drop to produce undesirable feedback. The **reactance** of the capacitor should be low compared to the **resistance** of the resistor being by-passed.

CAPACITOR, CERAMIC. See **ceramic capacitor.**

CAPACITOR, COMMUTATING. A **capacitor** used in gas-tube **rectifier circuits** to prevent the anode from assuming large negative voltages immediately after extinction. If the anode were permitted to go far negative before deionization was complete, some of the residual positive ions which would bombard the anode would be trapped, resulting in cleanup in non-reservoir types of tubes.

CAPACITOR, COUPLING OR BLOCKING. A **capacitor** incorporated in an electronic circuit to separate a-c and d-c components, and to isolate various parts of the d-c circuit while maintaining effective a-c connections.

CAPACITOR, DIFFERENTIAL. A variable, three-terminal capacitor (see **capacitor, electrical**) having a single rotor and two stators, arranged so that as capacitance is reduced on one side, it is increased on the other.

CAPACITOR, DRY ELECTROLYTIC. A **capacitor** whose dielectric is a thin film of gas formed by electrolytic action between two metal plates. In general the unit is not truly "dry," but contains a moist paste from which the gas is formed.

CAPACITOR FORMULAS. (1) The capacitance of n capacitors connected in parallel is

$$C = \sum_{1}^{n} C_i$$

(2) The capacitance of n capacitors connected in series is

$$\frac{1}{C} = \sum_{1}^{n} \frac{1}{C_i}$$

CAPACITOR, GUARD-RING. A parallel-plate capacitor (see **capacitor, parallel-plate**) in which the edge effect is eliminated by the presence of a guard ring surrounding one plate, and held at the same potential. This permits the calculation of capacitance from the geometry, hence the making of a capacitance standard.

CAPACITOR, GUARD-WELL. A modification of the guard-ring capacitor (see **capacitor, guard-ring**), with the guarded plate at the bottom of a well, to make standard capacitors of 0.1 $\mu\mu$f (and less) practical

CAPACITOR-INPUT FILTER. See **filter, capacitor-input.**

CAPACITOR INTEGRATOR. A device which makes use of the relationship

$$e_c = \frac{1}{C}\int i_c dt$$

found in a **capacitor.** A current proportional to the function to be integrated is fed into the capacitor, and the capacitor voltage is read as being the desired integral.

CAPACITOR LOUDSPEAKER. See **loudspeaker, electrostatic.**

CAPACITOR MICROPHONE. See **microphone, capacitor.**

CAPACITOR PICKUP. A phonograph pickup which depends for its operation upon the variation of its electric capacitance.

CAPACITOR, PRESSURE-TYPE. A capacitor which has a dielectric consisting of an inert gas, such as nitrogen under several atmospheres of pressure, the objective being higher operating voltages.

CAPACITOR RESONANCE FREQUENCY See **resonance frequency of a capacitor.**

CAPACITOR, TRIMMER. See **trimmer capacitor.**

CAPACITOR, VIBRATING (VIBRATING-REED DYNAMIC CAPACITOR). A **capacitor** whose capacitance is varied in a cyclic fashion so that an alternating emf is developed proportional to the charge on the insulated electrode. This device forms the basis for a type of electrometer. (See **vibrating reed electrometer.**)

CAPACITRON. An externally-fired, mercury-pool tube Formation of the arc occurs as a result of the sudden application of a high voltage between the cathode and an insulated **starter electrode.**

CAPACITY. (1) Extent of space; specifically cubic content or volume. (2) Power of receiving or absorbing, as exemplified by heat capacity, electrostatic capacity (**capacitance**), capacity for moisture. (3) Maximum output (4) Power, as exemplified by the carrying capacity of a stream.

CAPACITY, ELECTROSTATIC. See **capacitance.**

CAPACITY, HEAT. Quantity of heat required to raise the temperature of a body by a given amount, such as one degree Centigrade.

CAPACITY, SPECIFIC THERMAL. The heat capacity of unit mass of a substance, interchangeable with **specific heat.**

CAPILLARITY. The phenomena which are caused by **surface tension** and occur in fine bore tubes or channels. An example is the elevation (or depression) of liquid in a capillary tube partially immersed.

CAPILLARY. A cylindrical space of small radius, or a tube containing such a space.

CAPILLARY CORRECTION. A correction applied to mercury barometers, wide-bore thermometers, etc , for the effect of capillarity on the height of the column.

CAPILLARY ELECTROMETER. See **electrocapillarity.**

CAPILLARY PRESSURE. The pressure developed through capillary action, as in the **Jamin effect.**

CAPILLARY RISE. The elevation of liquid in a **capillary** tube above the general level. For capillaries of sufficiently small radius, it is

$$h = \frac{2\gamma \cos \phi}{\rho g}$$

where γ is the surface tension, ρ is the liquid density, ϕ is the angle of contact of the liquid with the capillary, g is the acceleration due to gravity, and r is the radius of the capillary.

CAPILLARY RISE METHOD. See **surface tension, methods of measurement.**

CAPILLARY THEORY OF SEPARATION. A theory of the separation of gases by flow through a porous medium, based on the concept of momentum transfer. The actual porous medium is treated as equivalent to a bundle of parallel capillary tubes. (*Physical Review* **75**, 1050; 1949.)

CAPILLARY TUBE METHOD. See **viscosity, measurement of.**

CAPSTAFF EFFECT. A photographic effect discovered by J. G. Capstaff in 1921. Sulfurous acid followed by a weak alkali is capable of extending the **sensitivity** of blue-sensitive films and plates to longer wavelengths. The effect appears to be due to the formation of a form of colloid silver and is of no practical value, although materials sensitive to the entire visible region (panchromatic) can be produced by bathing successively in sodium bisulfite (2%) and a weak solution of sodium carbonate, then washing in running water.

CAPTURE. Any process whereby an atomic or nuclear system acquires an additional particle.

CAPTURE EFFECT. An effect in F-M reception where the stronger signal of two stations on the same frequency completely suppresses the weaker signal.

CAPTURE GAMMA RAYS. The γ-rays emitted as the result of the capture of a particle by a nucleus.

CAPTURE, K-. See **K-electron capture.**

CAPTURE, RADIATIVE. (1) A nuclear capture process whose prompt result is the emission of electromagnetic radiation only. (2) In reactor technology, the capture of a neutron by a nucleus, with subsequent emission of a **γ-ray.**

CARAT. A unit of mass of 205 milligrams (in England, 205.31 milligrams). The carat is used widely to express weights of gems and precious metals, and this has given rise to another usage of the term carat, i.e., as a standard of purity of gold.

CARBON. Nonmetallic element. Symbol C. Atomic number 6.

CARBON ARC. A brilliant light source between two carbon rods which are first touched together to start and then separated a few mm. With d-c, the hottest point is the crater which forms on the anode (+ terminal). The flaming arc is produced by putting a core into each carbon rod containing some material such as strontium, calcium, cobalt or sodium salts which causes the most luminous area to be between the carbons. By putting a sample of an unknown into the anode crater, the unknown will be volatilized and its spectrum (arc spectrum) may be observed. The anode crater of a high current carbon arc with its temperature of over 5000°C is one of the hottest sources known in the laboratory.

CARBON BUTTON. See **button.**

CARBON CYCLE. A series of thermonuclear reactions, releasing great quantities of energy (by conversion from mass and by radiation) which are believed to furnish the energy radiated by many of the stars. This scheme was developed from theoretical considerations by H. A Bethe in 1939 (and simultaneously by C. F. von Weizsäcker). Various possibilities were tried, but the following series was the only one which gave results in agreement with the experimental facts:

$$C^{12} + H^1 \rightarrow N^{13} + \gamma$$
$$N^{13} \rightarrow C^{13} + {}_{+1}e + \nu$$
$$C^{13} + H^1 \rightarrow N^{14} + \gamma$$
$$N^{14} + H^1 \rightarrow O^{15} + \gamma$$
$$O^{15} \rightarrow N^{15} + {}_{+1}e + \nu$$
$$N^{15} + H^1 \rightarrow C^{12} + He^4,$$

where ${}_{+1}e$ indicates a **positron** and ν indicates a **neutrino.** (See **proton-proton chain.**)

The overall reaction results in the production of a helium atom, two positrons and

much energy, from four protons, the carbon atom that reacted initially being regenerated at the end of the process There are, of course, other probable side-reactions

CARBON CYCLE, ORGANIC. The cycle of processes by which living things utilize the carbon of the carbon dioxide of the atmosphere in their **metabolism.** The cycle includes **photosynthesis** of **carbohydrates** by plants from carbon dioxide and water in the presence of chlorophyll, with the aid of sunshine, the transformation of plant carbohydrates by animals into substances required in their structure and processes, the decay of animal bodies and excreta, aided by bacterial action, to return carbon dioxide to the atmosphere This term is included for differentiation from the nuclear reaction series by the same name

CARBON MICROPHONE. See **microphone, carbon**

CARBON-PILE REGULATOR. A control mechanism utilizing the variation of electrical resistance which occurs as a pile of carbon blocks is compressed

CARBON RECORDING. See **recording, carbon.**

CARBONIZED FILAMENT. A thoriated tungsten filament which has been treated with carbon to cause the formation of a coating of tungsten carbide This permits higher filament temperatures without corresponding evaporation of thorium

CARBONIZED PLATE. A carbon-blackened anode treated for the purpose of increasing the heat dissipation

CARBORUNDUM DETECTOR. See **detector, balanced.**

CARCEL UNIT. A French unit of luminous intensity defined as one-tenth of the output of the Carcel lamp which burns colza oil It is approximately 0 96 international **candle.**

CARCINOTRON. A backward-wave, **oscillator tube.**

CARDINAL POINTS OF A LENS SYSTEM. The **focal points,** the **principal points** and the **nodal points** constitute the cardinal points of a lens system

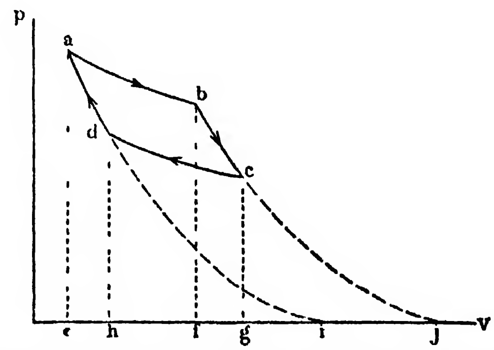
CARDIOID CONDENSER. An optical system for concentrating light on an object for a compound microscope It contains a **cardioid** surface of revolution as a mirror

CARDIOID MICROPHONE. See **microphone, cardioid.**

CAREY-FOSTER BRIDGE. See **bridge, Carey Foster.**

CAREY-FOSTER METHOD OF CALIBRATION. A method of calibrating a non-uniform slide-wire of a Wheatstone bridge (see **bridge, Wheatstone**) by interchanging two nearly equal resistances

CARNOT CYCLE. An ideal cycle of four reversible changes in the physical condition of a substance, useful in thermodynamic theory Starting with specified values of the variable temperature, specific volume, and pressure, the substance undergoes in succession (1) an isothermal (constant temperature) expansion, (2) an adiabatic expansion (see **adiabatic processes**) and (3) an isothermal compression to such a point that (4) a further adiabatic compression will return the substance to its original condition These changes are represented on the volume-pressure diagram respectively by *ab* *bc* *cd*, and *da* in the accompanying figure Or the cycle may be reversed *a d c b a*



Carnot cycle on v-p diagram *ab* and *cd* isothermals *bc* and *da* adiabatics

In the former (clockwise) case, heat is taken in from a hot source and work is done by the hot substance during the high-temperature expansion *ab*, also additional work is done at the expense of the thermal energy of the substance during the further expansion *bc* Then a less amount of work is done on the cooled substance, and a less amount of

heat discharged to the cool surroundings, during the low-temperature compression *cd*; and finally, by the further application of work during the compression *da*, the substance is raised to its original high temperature. The net result of all this is that a quantity of heat has been taken from a hot source and a portion of it imparted to something colder (a "sink"), while the balance is transformed into mechanical work represented by the area *abcd*. If the cycle takes place in the counterclockwise direction, heat is transferred from the colder to the warmer surroundings at the expense of the net amount of energy which must be supplied during the process (also represented by area *abcd*). The operation of the cycle thus illustrates the second law of **thermodynamics.**

CARNOT THEOREM. No engine operating between two given temperatures can be more efficient than a perfectly reversible engine operating between the same temperatures. (See **Carnot cycle.**)

CARRIER. (1) An entity capable of carrying electric charge through a solid—as, for example, **holes** and mobile **conduction electrons** in **semiconductors.** (2) A wave suitable for being modulated to transmit intelligence. The modulation represents the information; the original wave is used only as a "carrier" of the **modulation.** Usually thought of as a sinusoidal wave of radio frequency. (3) A quantity of an element which may be mixed with radioactive isotopes of that element giving a ponderable quantity to facilitate chemical operations. (4) A substance in ponderable amount which, when associated with a trace of another substance, will carry the trace with it through a chemical or physical process, especially a precipitation process. If the added substance is a different element from the trace, the carrier is called a nonisotopic carrier. (5) See **carrier of observed band system.** (6) See **hold-back agent.**

CARRIER-AMPLITUDE REGULATION. The change in amplitude of the **carrier wave** in an amplitude-modulated (see **modulation, amplitude**) transmitter when modulation is applied under conditions of symmetrical modulation. The term "carrier shift," often applied to this effect, should not be used.

CARRIER COLOR SIGNAL. In color television, the sidebands of the modulated color subcarrier (plus the color subcarrier, if not suppressed) which are added to the **monochrome signal** to convey color information.

CARRIER, CONTROLLED (VARIABLE OR FLOATING). A system of compound **modulation** wherein the carrier is amplitude-modulated by the signal frequencies in any conventional manner, but, in addition, the carrier is also amplitude-modulated in accordance with the envelope of the signal, so that the percentage of modulation, or **modulation factor,** remains relatively constant regardless of the amplitude of the signal.

CARRIER CURRENT. A relatively high-frequency a c superimposed on the ordinary circuit frequencies in order to increase the usefulness of a given transmission line. In the case of power systems, carrier currents of several kilocycles frequency are coupled to the 60-cycle transmission lines. These carrier currents may be **modulated** to provide telephone communication between points on the power system, or they may be used to actuate **relays** on the system. This latter use is known as carrier relaying. Carrier currents have greatly extended the usefulness of existing line facilities of the telephone and telegraph companies. Several carrier frequencies may be coupled to the lines already having regular voice or telegraph signals on them. Each of these carrier frequencies may be modulated with a separate voice or telegraph channel, and thus a given line may carry the regular signals plus several new carrier channels, each of which is equivalent to another circuit at regular frequencies. At the receiving end the various channels are separated by **filters,** and the signals demodulated, and then fed to conventional phone or telegraph circuits.

CARRIER DENSITY. In thermal equilibrium, the density, n, of electrons, and p, of **holes** in a non-degenerate **semiconductor are** related by the equation

$$np = N_c N_v \exp(-E_G/kT)$$

where E_G is the width of the **energy gap** between the **valence band** and the **conduction band,** and N_v, N_c are the effective densities of states in these bands, i.e.,

$$N_c = N_v = 2(2\pi mkT/h^2)^{3/2}.$$

CARRIER FREQUENCY. In a periodic **carrier,** the reciprocal of its period. The frequency of a periodic pulse carrier often is called the pulse-repetition frequency (prf).

CARRIER-FREQUENCY PULSE. See **pulse, carrier-frequency.**

CARRIER-FREQUENCY RANGE OF A TRANSMITTER. The continuous range of frequencies within which the transmitter may be adjusted for normal operation. A transmitter may have more than one carrier-frequency range.

CARRIER-FREQUENCY STABILITY OF A TRANSMITTER. A measure of the ability of the **transmitter** to maintain an assigned average frequency.

CARRIER, MAJORITY. The type of carrier in a **semiconductor** (see **carrier (1)**) constituting more than half of the total number of carriers.

CARRIER, MINORITY. (1) A carrier in a **semiconductor** (see **carrier (1)**) of type opposite to that characteristic of the material, e.g., a **hole** in an **n-type semiconductor.** The properties of **rectifiers** and **transistors** depend on the fact that minority carriers are not opposed by the space charge built up by the majority carriers, and hence may be injected rather easily into the material. (2) The type of carrier in a semiconductor, constituting less than half the total number of carriers.

CARRIER NOISE LEVEL (RESIDUAL MODULATION). See **noise level, carrier (residual modulation).**

CARRIER OF OBSERVED BAND SYSTEM. The molecule giving rise to the observed band system. The term carrier is applied in experiments where more than one molecular species is present.

CARRIER RELAYING. See **carrier currents.**

"CARRIER SHIFT" (ASYMMETRICAL MODULATION). The production of unequal amplitudes of positive and negative modulation peaks due to nonlinearities in the modulated stage. This effect may be regarded as a shift in carrier amplitude or power, and not as a shift in carrier frequency.

CARRIER SUPPRESSION. That method of operation in which the **carrier wave** is not transmitted.

CARRIER-TO-NOISE RATIO. The ratio of the value of the **carrier** to that of the **noise** after **selection** and before any nonlinear process such as amplitude limiting and detection.

CARRIER WAVE. See **radio communication.**

CARRY. (1) A condition occurring in addition when the sum of two digits in the same column equals or exceeds the base of the number system in use. (2) The digit to be forwarded to the next column. (3) The action of forwarding it.

CARRY, CASCADED. A system of executing the carry process in which carry information can be passed on to place $(N+1)$ only after the Nth place has received carry information or has itself produced a **carry.**

CARRY, COMPLETE. A system of executing the **carry** process in which all carries and any carries to which they give rise are allowed to propagate to completion.

CARRY, SELF-INSTRUCTED. A system of executing the **carry** process in which **information** is allowed to propagate to succeeding places as it is generated and without receipt of a specific signal.

CARRY, SEPARATELY-INSTRUCTED. A system of executing the **carry** process in which carry **information** is allowed to propagate to succeeding places only on receipt of a specific signal.

CARTESIAN COORDINATE. Numbers used to locate the position of a point relative to intersecting axes: two if in a plane and three in space. If the axes intersect at right angles, the coordinates are **rectangular** Cartesian, if the axes are not perpendicular, the coordinates are **oblique.** Since the latter are seldom used, the designation Cartesian frequently means rectangular Cartesian. See also **abscissa, ordinate,** and **rectangular coordinates.**

CARTESIAN OVAL. (1) A curve defined as the locus of a point P that moves so that its distance from the origin O (o,o) and the point A (a,o) in rectangular coordinates satisfy the relation $AP = \pm b \cdot OP \pm c$, where b and c are given positive constants. (2) An aplanatic refracting surface having the equation $na = n'a' =$ constant, where a and a' are the

distances from object and image, respectively, to the refracting surface.

CARVALLO PARADOX. If white light consists of a combination of infinitely long wave-trains, a spectrograph should show the spectrum both before the source is lighted and after it has gone out. The mistake lies in the assumption that the spectroscope selects light of exactly one wavelength. A spectroscope always selects a group of waves covering a small but finite range of frequency. Such a group may be considered as made up of an infinite series of pure harmonic waves which interact so as to give zero resultant before the source is lighted and shortly after it has gone out.

CASCADE. (1) Any connected arrangement of separative elements whose result is to multiply the effect, such as **isotope separation,** created by the individual elements. A bubble plate-tower is a cascade whose elements are the individual plates; a plant consisting of many towers in series and parallel is similarly a cascade whose elements may be considered to be either the towers or the individual plates. Similarly, an amplifier in which each stage except the first has as its input the output of the preceding stage is spoken of as a cascade amplifier. (2) See **tandem.**

CASCADE, IDEAL. A **cascade** wherein the number of elements in parallel and the flow in each stage vary continuously in such a way that a minimum number of separative elements are used to produce material of a specified concentration.

CASCADE SHOWER. A type of **cosmic ray shower** brought about when a high-energy electron, in passing through matter, produces one or more photons of energies of order of magnitude of its own. These photons are converted into electrons and positrons by the process of pair production. Then the secondary electrons produce the same effects as the primary, so that the process continues, and the number of particles increases. This cascade shower of electrons and positrons continues to build up until the energy level of product particles falls to a point where photon emission and pair production can no longer occur.

CASCADE THEORY (OF COSMIC RADIATION). Theory of multiplication of electrons, positrons and γ-rays in the passage of a cosmic ray particle through matter, especially through the atmosphere. Developed independently by Bhabha and Heitler and by Carlson and Oppenheimer. The γ-rays are produced by **bremsstrahlung** and in turn lead to **pair production.**

CASSEGRAINIAN TELESCOPE. A reflecting **telescope** in which a secondary convex mirror reflects the light from the collecting mirror back through a hole in the center of the collecting mirror. The first real image is commonly formed just behind the collecting mirror. (See **Newtonian** and **Gregorian telescopes.**)

CASSETTE. A film holder for photographic film.

CATACAUSTIC. A **caustic** produced by reflection.

CATADIOPTRIC. Pertaining to, produced by, or involving, both the reflection and the refraction of light.

CATAPHORESIS. Preferably called **electrophoresis.**

CATCHER. See **klystron.**

"CATCHER" GAP. In a **klystron,** the gap or grid which receives energy from the bunched or velocity-modulated electrons.

CATCHING DIODE. A diode used to "catch" or **clamp** a voltage at some point in a circuit.

CATELECTRODE. The **cathode.**

CATENARY. The locus of the equation

$$y = \frac{a}{2}(e^{x/a} + e^{-x/a}) = a \cosh \frac{x}{a}.$$

CATENARY CURVE OR CABLE. A homogeneous flexible cable, when suspended from two fixed points and allowed to hang freely, assumes the form of a **catenary** curve. The equation for a catenary cable with a linear mass density ρ is

$$y = \frac{A}{\rho g} \cosh \frac{\rho g x}{A}$$

where g is the acceleration of gravity and A is a constant equal to ρg times the perpendicular distance from the x-axis to the lowest point of the catenary. (See also **equilibrium of a flexible string.**)

CATHAMPLIFIER. An **amplifier circuit** with high input impedance which permits push-pull operation from an unbalanced source.

CATHETOMETER. A type of **comparator,** consisting of a telescope sliding on a vertical scale and provided with cross hair and a vernier. This instrument is used to measure heights of liquid columns, or other differences in level.

CATHODE. (1) In general, the electrode at which positive current leaves a device which employs electrical conduction other than that through solids. (2) In an **electron tube,** the electrode through which a primary stream of electrons enters the **interelectrode space.** (3) The negative terminal of an electroplating cell (i.e., the electrode from which electrons enter the cell, and thus at which positively charged ions (cations) are discharged) (4) The positive terminal of a **battery.**

CATHODE-BIAS ARRANGEMENT (SELF-BIAS ARRANGEMENT). The use of a resistor in the cathode circuit of an electron tube to cause the cathode to be at some potential above ground. If the **grid** is caused to be at ground potential, the net result will be that the grid is negative to the cathode by the amount that the cathode is positive with respect to ground. The grid-cathode voltage may thus be adjusted by changing the magnitude of the cathode resistance. Unless properly bypassed, the insertion of the resistance results in a certain amount of loss of amplification, because of negative **feedback.**

CATHODE, COLD. (1) A **cathode** in an **electron tube** or a **gas discharge tube,** that functions without the application of heat. (2) A specific cold cathode is an electrode used to furnish electrons by secondary emission, sometimes used in the ions source of a **mass spectrometer.**

CATHODE CURRENT. See **electrode current.**

CATHODE DARK SPACE. In a **gas discharge tube,** the dark band between the cathode glow and the **negative glow.** Also known as Crookes dark space or Hittorf dark space.

CATHODE, DIRECT-HEATED (FILAMENTARY). See **filament.**

CATHODE DISINTEGRATION. The destruction of the active area of a **cathode** by positive-ion bombardment.

CATHODE DROP. See **cathode fall.**

CATHODE FALL. In a **glow discharge tube,** the drop in potential (usually the larger part of the total potential) which occurs in the small distance between the cathode and the **plasma boundary.**

CATHODE FLICKER EFFECT. See **flicker.**

CATHODE FOLLOWER. A circuit in which the output load is connected in the **cathode circuit** of an electron tube, and the input is applied between the **control grid** and the remote end of the cathode load. The circuit is characterized by low output impedance, high input impedance, and **gain** less than unity under most operating conditions. (See **amplifier, grounded-plate.**)

CATHODE GLOW. At sufficiently high voltage, a glow exists about the negative terminal of an **arc.** By operating the arc at low pressure (in partial vacuum, as in a **gas discharge tube**), this glow may fill much of the tube, lying between the **cathode dark space** and the **Aston dark space.** A substance placed on the cathode will produce its characteristic spectrum in the cathode glow. Also called "*Glimmschicht method.*" However, in many discharges both the Aston dark space and the cathode glow will be absent or indiscernible.

CATHODE HEATING TIME (OF A GAS TUBE). The time required for the **cathode** to attain operating temperature with normal voltage applied to the heating element.

CATHODE HEATING TIME (OF A VACUUM TUBE). The time required for the time rate of change of the cathode current to reach maximum value. All electrode voltages should remain constant during measurement. The tube elements should all be at room temperature at the start of the test.

CATHODE, HOT. See **cathode, thermionic.**

CATHODE, INDIRECTLY HEATED (EQUIPOTENTIAL CATHODE, UNIPOTENTIAL CATHODE). A cathode of a **thermionic tube** to which heat is supplied by an independent heater element.

CATHODE, IONIC-HEATED. A **hot cathode** that is heated primarily by ionic bombardment of the emitting surface.

CATHODE, L-TYPE. An oxide cathode in which the emitting material is held in a reservoir instead of being applied in the form of a coating. Increased emission, life and resistance to gas poisoning result from this structure.

CATHODE LUMINOUS SENSITIVITY (OF A MULTIPLIER PHOTOTUBE). The quotient of **photocathode current** by incident **luminous flux.** The term photocathode current as here used does not include the **dark current.**

CATHODE MODULATION. See **modulation, cathode.**

CATHODE, PHOTO. A **cathode** in which the energy for emission of electrons is obtained primarily from light energy.

CATHODE PULSE MODULATION. See **modulation, cathode pulse.**

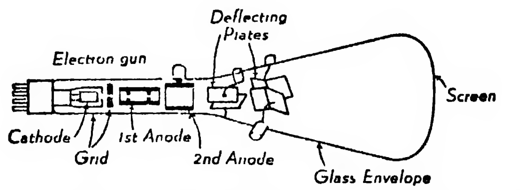
CATHODE RAY(S) (CATHODE STREAM). Originally, this term applied generally to a stream of electrons emitted from the cathode of a gas discharge tube, during its bombardment by positive ions. The term has been extended to denote any stream of electrons, such as those emitted by a heated filament. The emitted electrons are capable of causing **phosphorescence,** chemical changes, mechanical effects; they can raise the temperature of bodies which are subjected to their bombardment, penetrate solids, and give rise to **x-rays.**

CATHODE-RAY FURNACE. A very high temperature furnace used to heat small objects in a vacuum by bombarding them with intense electron beams.

CATHODE-RAY LAMP. An intense light source of small area obtained by directing a beam of electrons against a small block of refractory material which is thereby heated to incandescence.

CATHODE-RAY OSCILLOSCOPE. See **cathode-ray tube operated as oscilloscope;** also **oscilloscope, cathode-ray.**

CATHODE-RAY TUBE. A special form of vacuum tube used in various electronic applications, e.g., as the picture tube of the television receiver and as an oscilloscope tube. The tube consists fundamentally of three sections enclosed in an evacuated bulb. The first is the electron gun which produces and projects down the tube a beam of electrons. This gun has a **cathode,** usually indirectly heated, which emits a plentiful supply of electrons, then a **grid** which controls the number of electrons drawn towards the anode and finally the **anode.** Both the grid and anode are different in structure from the corresponding elements of the conventional vacuum **tube.** They consist of metal cylinders, coaxial with the cathode and closed at the end except for a small circular hole. Many of the electrons which are drawn towards the anode under the influence of the grid and anode voltages pass through these holes and are projected as a beam into the main part of the tube. Here they are focused upon the screen by electric or magnetic fields in a manner analogous to the focusing of light rays by a lens system. In passing down the tube the beam passes between two sets of plates, called deflecting plates, which are perpendicular to one another. A voltage applied to either of these sets will deflect the beam towards the positive plate. Sometimes the plates are omitted and coils outside the tube substituted. A current through the coils will set up a magnetic field and hence cause deflection of the beam. Finally the beam hits the screen which is a coating on the end of the tube of some material which will fluoresce under the impact of



the electrons. Reference to the figure will show the relative positions of the various parts of the tube. (See also **kinescope.**)

CATHODE-RAY TUBE AFTER-ACCELERATION (POST-DEFLECTION ACCELERATION). A system in which the electron beam of a **cathode-ray tube** receives a part of its energy by being accelerated after being deflected.

CATHODE-RAY TUBE DEFLECTING COILS. A pair of coils which provide the magnetic field for electromagnetic deflection of the electron beam.

CATHODE-RAY TUBE, DEFLECTION DEFOCUSING. The change in spot size or beam width due to the deflection process.

CATHODE-RAY TUBE, DEFLECTION SENSITIVITY. The ratio of deflection obtained on the screen to the voltage required to produce this deflection. Commonly used dimensions are volts, d-c, per inch (centimeter); volts, rms per inch (centimeter), volts, peak-to-peak per inch (centimeter).

CATHODE-RAY TUBE (OPERATED AS OSCILLOSCOPE OR TELEVISION PICTURE TUBE). The **oscilloscope** is used primarily for studying the current or voltage wave forms present in a circuit which is being investigated. If the voltage being studied is connected to one set of the deflecting plates it will cause the electron beam in the tube to move back and forth as the voltage varies. This will cause the fluorescent spot on the screen to move, and due to the persistence of the screen it will appear as a line. If now, another voltage is placed on the other set of plates it will move the beam and hence the screen spot, the resultant being a line pattern which is a combination of the effects of both voltages. Usually the second voltage is a sawtooth wave which gives linear (with respect to time) deflection of the spot and hence the pattern will be the same as if the first wave were plotted on conventional rectangular coordinates For current study either the voltage drop, caused by the current through a resistor, is used or the current is passed through the coils of the magnetic deflection type. For use as a television picture tube the picture signals are applied to the various electrodes so the fluorescence of the screen is a reproduction of the original scene being televised.

CATHODE-RAY TUNING INDICATOR. See **tuning indicator.**

CATHODE SHEATH. In a gas **discharge tube,** the region between the **cathode** and **plasma** across which the **cathode fall** appears.

CATHODE SPOT. See **mercury-arc tube.**

CATHODE SPUTTERING. A method of depositing extremely thin layers of metal on a surface. The metal to be deposited is used as a cathode which is heavily bombarded by positive ions in a medium vacuum, using a potential difference of some 10,000 volts. The small droplets of molten metal released by the intense cathode action are allowed to fall uniformly upon the object to be plated. Sputtering is done most successfully in an atmosphere of one of the rare gases.

CATHODE, THERMIONIC. In an **electron tube,** a **cathode** which emits electrons on heating. If the heating is accomplished by the passage of an electric current directly through the cathode, it is known as a directly-heated cathode, or **filament**; otherwise it is an indirectly-heated cathode.

CATHODE, UNIPOTENTIAL. Another name for an **indirectly-heated cathode,** so named because the total cathode is essentially at the same potential (See **cathode, thermionic.**)

CATHODE, VIRTUAL. The region in the **interaction space** of a **vacuum tube** where the electric field is zero.

CATHODOLUMINESCENCE. By bombarding a metal with electrons in an enclosure, as with **cathode-rays,** small amounts of the metal are vaporized in an excited state, and emit radiation characteristic of the metal.

CATHODOPHOSPHORESCENCE. Phosphorescence as a result of **cathode-ray** bombardment, as by the process described for **cathodoluminescence.**

CATION. A positively-charged ion. Cations are those ions that are deposited on the **cathode.** They travel in the nominal direction of the current. In electrochemical reactions they are designated by a dot or a plus sign placed above and behind the atomic or radical symbol as $H^{\cdot}$ or H^{+}, the number of dots or plus signs indicating the valence of the ion (See **cell; ion; anion.**)

In **electrolysis,** the cathode is negative, and attracts cations. In a **battery,** the deposition of cations on the cathode makes it the positive terminal.

CATIONIC CURRENT. That portion of the total current which is carried by cations.

CATHOLYTE. The liquid found in the immediate neighborhood of the **cathode** during **electrolysis.**

CAUCHY BOUNDARY CONDITION. Applied to a **partial differential equation** and consisting of the value of a function and its normal derivative, specified along a bounding curve. Such conditions are appropriate for **hyperbolic equations.** (See also **boundary condition, homogeneous.**)

CAUCHY CONVERGENCE TEST. If

$$\lim_{n\to\infty} |s_n|^{1/n} < 1,$$

then the infinite series

$$\sum_{n=1}^{\infty} s_n$$

converges absolutely. A corollary, known as the **Cauchy ratio test,** or sometimes as **d'Alembert's test,** involves

$$\lim_{n\to\infty} |s_{n+1}/s_n| = r.$$

If $r > 1$, the series converges; if $r < 1$, it **diverges**; if $r = 1$, the test fails and the series may either converge or diverge. For a more general theorem on the existence of a **limit,** also given by Cauchy, see **convergence.**

CAUCHY FORMULA FOR REFRACTIVE INDEX. There is no simple complete formula expressing the index of refraction of a medium as a function of wavelength. A number of semiempirical formulas have been used. One of these is

$$n^2 = 1 + \frac{A_1\lambda^2}{\lambda^2 - \lambda_1^2},$$

where A_1 is a constant characteristic of the material and λ_1 is an idealized absorption wavelength of the medium. When $\lambda_1 \ll \lambda$ this reduces to

$$n^2 = 1 + A_1 + \frac{A_1\lambda_1^2}{\lambda^2}$$

or $$n = A + \frac{B}{\lambda^2} \text{ (Cauchy Formula).}$$

A better approximation is

$$n = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} + \cdots$$

CAUCHY INTEGRAL. If a function of the **complex variable,** $f(z)$ is **analytic** and single-valued inside and on a simple closed curve C, then the function may be represented by the **Cauchy integral**

$$f(z) = \frac{1}{2\pi i}\int_C \frac{f(t)}{t - z}\,dt$$

for any value of z inside the curve. The only **singularity** within the contour is the simple pole at $t = z$. (See also **calculus of residues.**)

CAUCHY RELATIONS. If the forces between the atoms in a crystal lattice are **central forces,** and if every atom is in a center of symmetry (see **symmetry, center of**), then certain relations hold between the **elastic moduli** of the unstrained crystal. **Ionic crystals** satisfy these conditions fairly well, but metals do not, because the metallic bond is non-central, offering little resistance to shearing of the lattice.

CAUCHY-RIEMANN EQUATION. If $\partial u/\partial x = \partial v/\partial y$ and $\partial u/\partial y = -\partial v/\partial x$, where u and v are both functions of x and y, these equations will be satisfied for an **analytic function** $(u + iv)$ of the **complex variable** $z = (x + iy)$. They are often used to show that such a function is **analytic.** (See also the **Laplace equation.**)

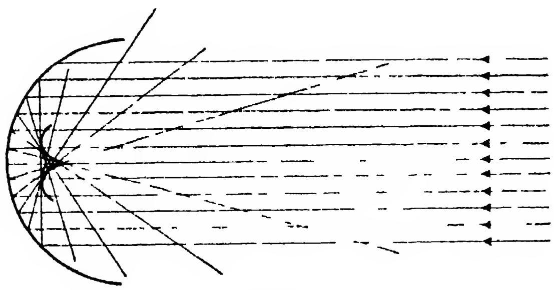
CAUCHY THEOREM. If $f(z)$ is an **analytic function** of a **complex variable** z which has no **singularities** within or on a given closed curve C, then

$$\int_C f(z)dz = 0,$$

where the integral is extended over the entire **contour** C.

CAUSALITY. (1) The hypothesis that a precisely determined set of conditions will always produce precisely the same effects at a later time. Classical physics was based on firm belief both in philosophical causality and in the idea that the precise determination of the initial conditions was possible in principle. Quantum mechanics is based rather on the **Heisenberg uncertainty principle,** which indicates that such precise determination is impossible. (2) Condition that an event cannot produce any effect outside of its future **light cone.** (See **Kramers-Kronig dispersion formula.**)

CAUSTIC. An envelope curve giving the boundaries of an intially parallel beam after



Caustic

reflection or refraction by an optical system which has spherical aberration.

CAVENDISH EXPERIMENT. An experimental method developed in the eighteenth century by Henry Cavendish to measure the universal constant of gravitation "G." The method employs a torsion balance to which are fastened two metal spheres. The controlled presence of other large masses causes the balance to deflect. From a knowledge of the masses and the force of attraction, the constant G can be computed by the application of the Newton law of universal gravitation. (See **gravitational constant.**)

CAVITATION. The formation of local cavities in a liquid as a result of the reduction of total pressure. For non-degassed liquids, these cavities are filled with the gases dissolved in the liquid and are produced whenever the instantaneous pressure falls below the vapor pressure. This effect is sometimes called pseudo-cavitation, to distinguish it from the effect in pure degassed liquids, where an actual rupture of the medium occurs (at much higher sound pressures). Collapse of such cavities produces very large impulsive pressures that may cause considerable mechanical damage to neighboring solid surfaces.

CAVITATION NUMBER. A non-dimensional parameter,

$$\lambda = \frac{p_0 - p'}{\frac{1}{2}\rho v^2}$$

where p_0 is the pressure at a reference position in the flow, p' is the vapor pressure. $\frac{1}{2}\rho v^2$ is the kinetic pressure. It provides a measure of the risk of **cavitation** occurring in a particular flow system.

CAVITY RESONATOR. A space normally bounded by an electrically conducting surface in which oscillating electromagnetic energy is stored, and whose **resonance frequency** is determined by the geometry of the enclosure.

CAYLEY-KLEIN PARAMETER. One of a set of four quantities used to describe the orientation of a rigid body. They are not linearly independent but may be expressed in terms of the **Euler angles.** When combined into matrix equations they are related to the **Pauli spin matrices** which occur in quantum mechanics (See also **Euler-Rodrigues parameters.**)

CEILING. In general, the total distance from ground or water vertically to the base of lowest cloud layer that, in summation with all lower layers of clouds and obscuring phenomena, covers 0.6 or more of the sky.

CELESTIAL MECHANICS. The term celestial mechanics is applied to that field of astronomical study and research which deals with the motions of two or more bodies in space under the influence of their mutual gravitational attractions. The fundamental elements of the subject are found in the Newtonian law of universal gravitation, the laws of motion, and the Keplerian laws of planetary motion. In the classical theory we find space of three dimensions treated, with time considered as an independent variable. Within recent years some slight modifications of the classical theory, particularly when the time interval is very long or velocities and accelerations are very high, have become necessary on account of the theory of **relativity.** Under the general heading of celestial mechanics we find such problems discussed as the development of the various methods for orbit computation, methods for computing perturbations, and solutions of the problem of three bodies.

CELL. (1) A limited region of space, specifically in **phase space.** (2) An electrical cell. (See **cell, electric.**) (3) A physical device of small dimensions, used as part of a larger device, e.g., **Kerr cell** or **absorption cell.**

CELL, AVAILABLE ENERGY OF. The electrical energy available from a reversible cell is the thermodynamic **free energy change** of the process occurring in the cell.

CELL, CLARKE. See **cell, standard.**

CELL, CONCENTRATION. An electric cell (see **cell, electric**) in which the electrical energy is derived from the **free energy** change accompanying the transfer of a substance from a system of high concentration to one of low concentration. If the transfer is across the interface between two solutions of the same electrolyte at different concentrations, there is a direct transfer of electrolyte. On the other hand, two similar voltaic cells containing electrolyte at different concentrations, connected back-to-back, form a concentration cell in which the transfer of electrolyte is indirect.

CELL, CONDUCTIVITY. See **conductivity cell.**

CELL CONSTANT. The **conductivity** of an **electrolyte** is inversely proportional to the observed resistance of the **conductance cell.** The proportionality constant depends on the geometry of the cell, and is called the cell constant. It is most readily determined by measuring an electrolyte of known conductivity.

CELL, DISPLACEMENT. An electric cell (see **cell, electric**) in which the essential chemical reaction is the **ionization** and entry into solution of atoms of one element, and the **discharge** and deposition from solution of the ions of another. A well-known displacement cell is the Daniell cell, in which metallic zinc dissolves in a zinc sulfate solution, yielding zinc ions, while copper ions are discharged and deposited from a copper sulfate solution, with accompanying flow of electricity in an external circuit.

CELL, DRY. An electric cell (see **cell, electric**) in which the electrolyte is a damp paste, rather than a free liquid, and thus produces a device more convenient for many purposes, including portable applications in flashlights. Another common feature of design of dry cells is that one of the electrodes is made in the shape of a cup which contains the electrolyte-depolarizer mixture, and in which the other electrode is centered.

CELL, ECHELON. A hollow glass vessel of triangular horizontal cross-section used in absorption **spectrography,** because of its convenience in adjusting the thickness of the layer of the absorbing liquid to any value up to that represented by the altitude of the triangle constituting the section of the cell.

CELL, ELECTRIC. An apparatus for the transformation of chemical into electrical energy or the reverse. The essential parts of the cell are the containing vessel, the electrodes, and the electrolyte solution. The electrodes are usually plates of metal or carbon immersed in the electrolyte solution; the electrode by which the current leaves the cell is termed the **cathode,** and that through which the current enters is called the **anode.**

CELL, ELECTRODE CONCENTRATION. A concentration cell (see **cell, concentration**) having a uniform electrolyte, and electrode of the same metal at different concentrations, as in different concentration amalgams.

CELL EMF (FORMULA FOR). Since the electrical work done by a reversible cell equals the decrease of free energy in the cell reaction

$$-\Delta G = W = EIt = Eq = EnF$$

It follows that

$$E = -\frac{\Delta G}{nF}$$

where ΔG is the free energy change, n, the number of faradays passing through the cell, and F is **faraday** (96,500 coulombs).

CELL, GRAVITY. An electrolytic cell in which the separation between the two ionic solutions is maintained by means of gravity. An example is the **Daniell cell** in which a cupric sulfate solution in contact with a copper electrode is below a zinc sulfate solution in contact with a zinc electrode. The difference in specific gravity of the solutions prevents, or at least retards, mixing.

CELL, HALF. A voltaic **cell** can be considered as two half-cells in series, each containing electrolyte and a single electrode. (See single **electrode potentials.**)

CELL INTERNAL RESISTANCE. If a **cell** having an open-circuit emf E is connected to a resistance R, the current will be

$$I = \frac{E}{R + r}.$$

The resistance r contributed to the circuit by the cell is the internal resistance.

CELL, IRON-NICKEL. A **secondary cell** (Edison battery) having electrodes of iron and of nickel oxide. The electrolyte is a solution of potassium hydroxide.

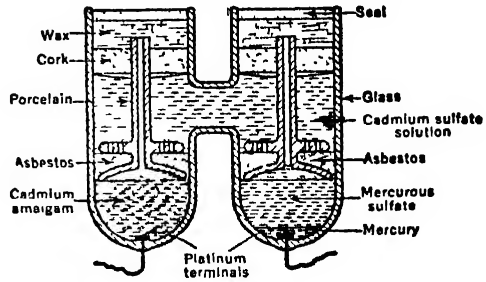
CELL, LECLANCHÉ. The Leclanché cell is of particular interest, since in a special form it is the common "dry-cell." It has a carbon cathode surrounded by manganese dioxide as a **depolarizer,** a zinc anode, and a solution of ammonium chloride as the electrolyte.

CELL, PRIMARY. An electric **cell** in which electric energy is obtained as the result of a chemical reaction or reactions. Although the reactions are approximately reversible, the primary cell as defined is not arranged to operate reversibly, cells so constructed being called secondary cells. (See **cell, secondary.**)

CELL, REVERSIBLE. An electric cell (see **cell, electric**) in which the rate of chemical reaction varies continuously and reversibly with applied external emf, and goes through zero at a particular emf.

CELL, SECONDARY. An electric cell (see **cell, electric**) in which the interacting substances may be restored to their original chemical form by sending a direct current of electricity through the cell in reverse direction to that of the discharge. Secondary cells are commonly used to store and furnish electricity, i.e., to act as a storage battery.

CELL, STANDARD. Precise measurement of electromotive force, as with a **potentiometer,** require a constant, known source of voltage. The only practicable means of supplying this is by some special type of electrolytic cell. Of these, two have been highly developed and much used. The older is the Clarke standard cell, which, as improved by Carhart, has a mercury cathode and an amalgamated zinc anode. The cathode is submerged in a mercurous sulfate paste, and the electrolyte is a solution of zinc sulfate saturated at 0°C. The whole is sealed in a suitable glass tube. This cell has an electromotive force of 1.440 volts at 15°C, with a decrease of 0.00056 volt per degree rise in temperature. In 1891 Weston substituted cadmium amalgam for zinc, and a saturated solution of cadmium sulfate for the zinc sulfate electrolyte, the whole in an *H*-shaped tube. The Weston normal cell has a somewhat lower voltage than the Clarke (1.018636 volts at 20°C), but its temperature coefficient is practically negligible. An unsaturated type of Weston cell is much used commercially in the



Cross-section of standard Weston normal cadmium cell

United States. It is neither as permanent nor as reproducible as the saturated cell, but is portable and is ten times less sensitive to temperature changes.

CELL, TYPES OF. The emf in a voltaic **cell** can be due to the presence of an electrolyte concentration gradient, an electrode solubility difference, an electrode reducibility difference, or the use of non-mixed different electrolytes.

CELL, VOLTAIC. (1) An electric cell (see **cell, electric**). (2) An electric cell consisting of two electrodes of dissimilar metals immersed in a solution which acts chemically upon one or both of them, thus producing an electromotive force; this type of cell derives its name from the physicist Volta, who discovered the effect.

CELS. Abbreviation for Celsius. (See **temperature scale, Celsius.**)

CELSIUS. See **temperature scale, Celsius.**

CENT. (1) The interval between two sounds whose basic frequency ratio is the twelve-hundredth root of two. The interval, in cents, between any two frequencies is 1,200 times the logarithm to the base 2 of the **frequency ratio.** Thus 1,200 cents = 12 equally tempered **semitones** = 1 octave. (2) In nuclear technology, a unit of reactivity.

CENTER FREQUENCY. See **carrier frequency.** Center frequency is commonly used only for aural transmitters.

CENTER, INSTANTANEOUS. The point about which a body having general **motion** may be considered to be in pure rotation (i.e.,

without **translation**) for any instant. The instantaneous center is not necessarily on the body; in fact, it can be, in the case of rectilinear motion, infinitely distant.

CENTER OF ACTION. Any one of several large areas of high and low barometric pressure, changing little in location, and persisting through a season or through the whole year. Changes in the intensity and positions of these pressure systems are associated with widespread weather changes.

CENTER OF AREA. See **centroid.**

CENTER OF BUOYANCY. The point through which the resultant of the **buoyancy** forces on a submerged body act It is coincident with the **center of gravity** of the displaced fluid.

CENTER OF DISPLACEMENT. The **center of gravity** of the fluid displaced by a floating body.

CENTER OF GRAVITY. For an extended body or collection of particles subject to the earth's gravitation, the point through which the resultant force of gravity acts (i e, the weight of the body or collection) no matter how the body is oriented. In a uniform gravitational field in which the ratio of gravitational force to mass is always the same, the center of gravity is the same as the **center of mass.**

CENTER OF INERTIA. See **center of mass.**

CENTER OF INVERSION. A **symmetry element** possessed by certain crystals, whereby the crystal can be brought into self-coincidence by the operation $\mathbf{r} \rightarrow -\mathbf{r}$, where $\mathbf{r}$ is the vector position of a point in the crystal referred to the center of inversion

CENTER OF MASS. That point in a body about which the sum of the moments of all the individual masses constituting the body is zero. If the individual (point) masses be called m_j and the vector displacement of m_j from some fixed origin be called $\mathbf{r}_j$, the center of mass is located $\mathbf{r}$ from the origin, where

$$\mathbf{r}\Sigma m_j = \Sigma m_j \mathbf{r}_j$$

the summation being extended over all of the masses constituting the body.

CENTER-OF-MASS SYSTEM. In general, any frame of reference moving with the center of mass of a system. Calculations in the center of mass system are often simpler than in other coordinate systems because the total **momentum** in the former is always zero. (See **laboratory system.**)

CENTER OF OSCILLATION (CENTER OF SUSPENSION, CENTER OF PERCUSSION). The frequency of oscillation of a physical pendulum is given by

$$f = \frac{1}{2\pi}\sqrt{\frac{gl}{k^2 + l^2}},$$

where l is the distance from the point of suspension to the center of mass, and k is the **radius of gyration.** A simple pendulum having the same frequency will be of length

$$l_1 = \frac{k^2 + l^2}{l}.$$

The point which lies at a distance l_1 from the point of suspension on the line through the point of suspension and center of mass is called the center of oscillation If the physical pendulum were to be suspended from this point, its frequency would be the same as for the original point of suspension (See also **pendulum, physical; pendulum, simple.**)

CENTER OF PERCUSSION. That point (with respect to a given point of suspension) on a rigid rod, like a tennis racket or baseball bat, such that an impulse applied perpendicular to the rod at the point produces no impulsive reaction at the original point of suspension. The center of percussion coincides with the **center of oscillation.**

CENTER OF PRESSURE, HYDROSTATIC. The point through which the resultant of the forces on a surface due to hydrostatic pressure acts The center of pressure on a vertical surface lies at a depth (below the surface of a liquid) equal to the quotient of the areal moment of inertia (second moment of area) by the first moment of area, the areas being measured on the vertical surface and both moments being taken about a line in the liquid surface directly above the vertical surface.

CENTER OF SYMMETRY. A point within a body or within a set of points, having such location that for every point there is a similar point on a line passing through the first point and the center of symmetry, the distance of the two points from the center being identical.

CENTER OF SUSPENSION. See **center of oscillation.**

CENTER OF VOLUME. The **center of mass** of a **homogeneous region.** The rectangular coordinates are given by

$$\bar{x} = \frac{\int x dV}{V}$$

$$\bar{y} = \frac{\int y dV}{V}$$

$$\bar{z} = \frac{\int z dV}{V}$$

where the integration is taken in each case over the whole volume V of the region

CENTERING CONTROL. In cathode-ray-tube devices, a **potentiometer** which enables the viewer to move the image back and forth or up and down on a screen Horizontal and vertical centering each requires a separate control

CENTI-. A prefix, used with many physical units, denoting one one-hundredth Thus 100 centimeters = 1 meter; 100 centipoises = 1 poise

CENTIGRADE. See **temperature scale, Centigrade.**

CENTIGRAM. One one-hundredth of a **gram.**

CENTIMETER. One one-hundredth of a **meter.**

CENTIPOISE. A standard unit of **viscosity,** equal to 0.01 **poise,** the c g s unit of viscosity Water at 20°C has a viscosity of nearly 1 centipoise.

CENTRAL FORCE. A force acting along the line joining two centers, as, for example, the electrostatic attraction between unlike charges.

CENTRAL FORCE, NUCLEAR. See **nuclear force.**

CENTRIFUGAL. Moving outward or directed outward, in the sense of away from a center.

CENTRIFUGAL FORCE. A radially outward force experienced by an observer in a reference frame which is rotating at an **angular velocity** ω with respect to an **inertial frame** (cf. **Coriolis effects** (2)). The centrifugal force is the reaction to the **centripetal force** necessary to hold the observer at a fixed point in the rotating frame and thus has a magnitude equal to and a direction opposite to the centripetal force.

CENTRIFUGE. An apparatus for the separation of substances by the application of centrifugal force.

CENTRIFUGE, CONCURRENT. The application to isotope separation of the centrifugal cream separator. One or more streams of gas enters at one end of the centrifuge and the partially-separated isotopes are removed in two or more streams at the other end.

CENTRIFUGE, COUNTERCURRENT. In this device counter-current circulation is established in a centrifuge either thermally or mechanically By the circulation of the gas the radial concentration gradient is converted into an axial gradient

CENTRIFUGE, EVAPORATIVE. A batch-separating device wherein a mixture to be separated is introduced into the centrifuge as a liquid The vapors are removed from a point near the axis of the centrifuge, having been separated by diffusion through the centrifugal field

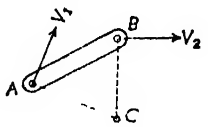
CENTRIPETAL. Moving inward, or directed inward, in the sense of toward a center.

CENTRIPETAL ACCELERATION. (1) The acceleration towards the center to which any particle moving in a circular orbit is subject This acceleration is equal to v^2/r, where v is the orbital velocity and r the radius (2) More generally, that part of the radial component of the acceleration of a particle moving in any curved path which is equal to the magnitude of the radius vector from the instantaneous center of rotation multiplied by the square of the instantaneous angular velocity about that center (See **Coriolis effects.**)

CENTRIPETAL FORCE. The force necessary to impart **centripetal acceleration** to a body For a body of mass m moving about a fixed axis at a distance r and with an angular velocity ω, the centripetal force is $-m\omega^2 r =$

$-mv^2/r$, where v is the linear velocity of the particle and where the negative sign indicates that the force is directed radially inward. Effects such as the rupture of a rotating body or the outward skidding of an automobile in rounding a corner are often discussed as effects of **centrifugal force**, but are better described as being due to the insufficiency of the centripetal forces (elastic stresses or the frictional force of the wheels on the road) to maintain the masses at constant distance from the center of rotation.

CENTRODE. The path of the instantaneous center of a plane figure having plane motion, that is, motion resulting when all points in the figure move in parallel fixed planes, is called the centrode. Any plane body having plane motion which is neither entirely rectilinear nor entirely rotative, but a combination of the two, may be considered at any instant as having rotary motion about a moving point called the instantaneous center of rotation. As shown in the illustration the plane body



AB has a motion such that the velocity of A is V_1 while the velocity of B is V_2. At the instant corresponding to the position shown for AB the body must be rotating about a point C, which is located at the intersection of the perpendiculars to V_1 and V_2 dropped from A and B respectively. C is the instantaneous center of rotation of AB and the centrode is the path traced by the point C while AB is in motion. (See also **center, instantaneous.**)

CENTROID (CENTER OF AREA). The **center of mass** of a two-dimensional homogeneous region. For a plane, the coordinates are given by

$$\bar{x} = \frac{\int x dA}{A}$$

$$\bar{y} = \frac{\int y dA}{A}$$

where the integrals are taken over the complete area, A, of the region.

CERAMAG. Trade name for a ferrite core material.

CERAMIC CAPACITOR. A capacitor whose dielectric is composed of a ceramic material. One form, using a high **Q** dielectric such as steatite, produces a very stable capacitor which may be made with a variety of temperature coefficients. Another type, giving a much larger capacitance per unit volume, employs a high dielectric constant material such as barium titanate. Unfortunately, these capacitors have a lower **Q**, and a lower leakage resistance, which restrict their application.

CERAUNOGRAPH. An electronic instrument for recording the occurrence of lightning discharges.

CERENKOV COUNTER. An apparatus for detecting the **Cerenkov radiation** and determining its directional characteristics.

CERENKOV RADIATION. Radiation emitted by a high-energy charged particle moving in a medium having an index of refraction considerably greater than unity. This radiation is due to the effect of the difference between the high velocity of the particle, which may be close to that of light in a vacuum, and the lower velocity of its associated electric and magnetic fields, which have velocity equal only to the velocity of light in a vacuum divided by the index of refraction of the medium.

CERIUM. Rare earth metallic element. Symbol Ce. Atomic number 58.

CERROBEND. A solder which has a melting point of 70°C.

CERROSEAL. A solder which has a melting point of 120°C, and contains indium.

CESIUM. Metallic element. Symbol Cs. Atomic number 55.

CH. Common identification for an iron-cored inductor or choke coil.

CHADWICK-GOLDHABER EFFECT. A term applied to nuclear reactions brought about by bombardment with **γ-radiations.**

CHAFF. Metal foil strips used as **window** to confuse enemy radar.

CHAIN. See **radioactive series.**

CHAIN DECAY. See **radioactive series.**

CHAIN DISINTEGRATION. See **radioactive series.**

CHAIN REACTION. A reaction in which one of the agents necessary to the reaction is itself produced by the reaction so as to cause like reactions. In the neutron fission chain reaction, a neutron plus a fissionable atom causes a fission resulting in a number of neutrons which in turn cause other fissions.

CHANGE OF STATE. Transformation from one to another of the three states of matter—gaseous, liquid, or solid.

CHANNEL CAPACITY. The number of symbols per second which may be transmitted in a given **channel.**

CHANNEL EFFECT. In junction transistors (see **transistor, junction**) the flow of current between emitter and collector which circumvents the base region, due to some condition such as surface leakage.

CHANNEL, FREQUENCY. The band of frequencies which is associated with a single unit of intelligence in a communications system. Thus it applies to the band of frequencies radiated by a broadcast station, or to the band of frequencies which must be handled by a carrier system to handle a single conversation. In the various systems the application of intelligence to a given frequency will generate certain other frequencies which are then associated with the original in some manner to convey the intelligence to the receiver. This band of frequencies then determines the response characteristics which the receiver (or other units of the system) must have for satisfactory results. Thus in conventional broadcasting the various stations use channels about 10 kc wide; in frequency modulation the present channel is about 200 kc; in television it is 5 or 6 megacycles; in carrier telephony it is only about 3 kc.

CHANNEL, RADIO. See **radio channel**

CHANNELING. (1) The extra transmission of particles through a medium containing voids, due to the presence of the voids. (2) The additional transmission of the material containing voids as compared to a homogeneous material with average density the same as the material with the voids.

CHANNELING EFFECT FACTOR. Attenuation per unit length of equivalent homogeneous material divided by attenuation per unit length of the material containing voids.

CHAPMAN EQUATION. An equation expressing the **viscosity** of a gas in terms of certain molecular constants. This relationship has been simplified to the expression:

$$\eta = \frac{(0.499)mc}{\sqrt{2}\pi\sigma^2(1 + c/T)}$$

in which η is the viscosity, m is the mass of a molecule, c is its average speed, σ is the collision diameter of the molecule, c is **Sutherland constant,** and T is the absolute temperature.

CHARACTER. (1) The **trace** (sum of the diagonal elements) of a matrix **representation** of a **group.** The character of all elements in a given **class** of the group is the same (2) One of a set of elementary symbols which may be arranged in ordered aggregates to express information.

CHARACTERISTIC. (1) Describing certain curves used in the study of **partial differential equations;** (2) the integral part of a **logarithm,** used to locate the decimal point of the number; (3) for characteristic equation, matrix, and value, see **eigenfunction and eigenvalue.**

CHARACTERISTIC EQUATION. (1) A class of equations connecting those variables, such as temperature, pressure and volume, which define the physical condition of a given substance and are called variables of state.

The **ideal gas law** and the **Boyle-Charles** law represent approximately the behavior of all gases, but if one wishes to be accurate, some modification of these must be sought which will take account of the differences between individual gases. The best known characteristic equation for gases is that of van der Waals Using the same notation as for the ideal gas law, this may be written

$$\left(p + \frac{a}{v^2}\right)(v - b) = RT.$$

(Here, however, the volume is not in liters but is in terms of the volume of the same body of gas at standard temperature and pressure; and the pressure is in atmospheres.) a and b are constants characteristic of the gas in question. They are very small; if they were zero we should have the ideal gas law. Following are their approximate values for certain gases:

Gas	a	b
Ammonia	0.00831	0.00165
Helium... ...	0.00007	0.00106
Hydrogen	0.00049	0.00119
Nitrogen....	0.00277	0.00175
Oxygen ..	0.00271	0.00142

Characteristic equations of this sort are also known as **equations of state.** (See also equations under names of individuals, such as **Beattie and Bridgeman equation; Berthelot equation;** etc.)

(2) Equations which have solutions, subject to particular boundary conditions, only for certain specific parameters occurring in them. (See **eigenfunction** and **eigenvalue.**)

CHARACTERISTIC IMPEDANCE (OF A CIRCULAR WAVEGUIDE). See **impedance characteristic (of a circular waveguide).**

CHARACTERISTIC IMPEDANCE (OF A RECTANGULAR WAVEGUIDE). See **impedance, characteristic (of a rectangular waveguide).**

CHARACTERISTIC TELEGRAPH DISTORTION. See **distortion, characteristic telegraph.**

CHARACTERISTIC TEMPERATURE. See **Debye temperature.**

CHARACTERISTIC WAVE IMPEDANCE. See **impedance, characteristic wave.**

CHARACTERISTIC WAVELENGTH OF A MEDIUM. The characteristic velocity (see **velocity, characteristic**) divided by the frequency: $1/f\sqrt{\mu\epsilon}$.

CHARACTERISTIC X-RAYS. See **x-rays, characteristic.**

CHARACTERIZATION FACTOR. A factor obtained by dividing the cube root of the boiling point (in degrees Rankine) by the specific gravity at 60°F. It is useful in the investigation of oils.

CHARACTRON. A trade name for a particular, modern type of **cathode-ray tube.** It is often used to display letters or numbers.

CHARGE. (1) A quantity of **electricity,** measured in **coulombs** or related units. The flow of charge per unit time is the **electrical current.** (2) A term applied to flux, especially in the flux-charging concept of **magnetic amplifier** operation, commonly expressed as volt-time integral.

CHARGE (LOAD). In **induction heating** and **dielectric heating** usage, the material to be heated.

CHARGE, AVERAGE DENSITY OF. The total charge in a region divided by the volume of that region.

CHARGE, BOUND. Those electric charges on the surface of a **dielectric** whose surface density is equal to the polarization within the dielectric. Such charges are bound in the sense that they result from the creation and reorientation of dipoles within the dielectric. The total amount of bound charge throughout the volume of any dielectric is zero. Bound charges are distinguished from free charges. (Cf. **charge, free; electrostatics.**)

CHARGE CONJUGATION. The theoretical operation of changing the signs of all electric charges and electromagnetic fields in a system.

CHARGE-CURRENT DENSITY FOUR VECTOR. The four functions of position and time $j_\mu(r,t)$ where j_1, j_2, j_3, are the components of electric current density, and $j_4 = ic\rho$, where ρ is the charge density. For a Dirac electron field (see **Dirac electron theory**),

$$j_\mu = iec\bar{\psi}\gamma_\mu\psi$$

where $\bar{\psi}$ is the **adjoint wave-function.**

CHARGE DENSITY. In electrostatics, we deal both with finite, point charges, and distributed charges. (1) A distributed charge can be described in terms of its density (coulombs per cubic meter) at each point of the region of interest. The density is a three-dimensional analog of a simple derivative. (See the **Poisson equation.**) (2) The term is also used to refer to the **surface charge density,** the charge per unit area.

CHARGE, DRIFT VELOCITY OF. The average velocity of the individual charges in a group. For example, in an **electron tube,** individual electrons move with different velocities, but the average, or drift, velocity yields the net current.

CHARGE, ELECTRIC. See **electrostatics.**

CHARGE, ELEMENTARY. The unit charge of electricity, the charge on the **electron,** approximately 4.8022×10^{-10} **electrostatic units (statcoulombs)** or 1.6019×10^{-19} coulombs

CHARGE, FREE. Electric charges on the surface of a **conductor** or those charges on the surface of a dielectric which are not bound (cf **charge, bound**). When free charges occur at the interface of dielectrics, there is a discontinuity in the normal component of the electric displacement vector at the interface, the magnitude of the change being the surface density of free charges or 4π times that quantity, dependent on whether rationalized or unrationalized units are employed (See **electrostatics, Gauss' law.**)

CHARGE INDEPENDENCE. Hypothesis that the neutron-proton, proton-proton, and neutron-neutron forces are all equal for the same spin states, when the parts of the interactions that are explicitly electromagnetic have been subtracted out.

CHARGE INVARIANCE. Hypothesis that nucleon-nucleon interactions are invariant under rotations in **isotopic spin** space. One consequence of this is the **charge independence** of nuclear forces.

CHARGE-MASS RATIO. The relationship between the electric charge of a particle and its mass, so important in the physics of electrons, ions, and other electrified bodies of molecular order.

CHARGE, POLARIZATION. See **polarization charge.**

CHARGE - TRANSFER SPECTRUM. See **spectrum, charge-transfer.**

CHARGED SYSTEM, ENERGY OF. See **energy of charged system.**

CHARGED SYSTEM, FORCE OF. See **force of charged system.**

CHARGER-READER. Any auxiliary device used to charge and read pocket chambers or thimble ionization chambers. (See also **condenser r-meter.**)

CHARLES LAW. The coefficients of expansion of all gases are nearly the same, namely, about $\frac{1}{273}$ of the volume at 0°C per centigrade degree The law, stated by Charles in 1787 and independently by Gay-Lussac in 1802 (hence sometimes called Gay-Lussac's law), is not strictly true for non-ideal gases. Regnault obtained the following values of the volume coefficient, at one atmosphere pressure, for various gases:

Air .	0 0036706
Hydrogen	0 0036613
Carbon dioxide	0 0037099
Sulfur dioxide	0 0039028
Carbon monoxide	0 0036688
Nitrous oxide	0 0037195
Cyanogen	0 0038767

None of these is far from $\frac{1}{273} = 0.003663$, which is therefore commonly taken as the expansion coefficient for gases; especially as the value for hydrogen, commonly used in the standard gas thermometer, is very near it. If the pressure as well as the volume is allowed to vary, the behavior of the ideal gas must be expressed by the **Boyle-Charles law** or the **ideal gas law.**

CHASSIS. The metallic base on which the parts of electronic circuits are mounted.

CHATTOCK GAUGE. A tilting **manometer** which balances the pressure to be measured against the pressure head caused by the tilt which can be measured accurately The null indication depends on the observation of the motion of the interface between two immiscible liquids of nearly equal density.

CHECK PROBLEM. A problem whose incorrect solution indicates an error in the operation or programming of a **computer.**

CHEESE ANTENNA. See **antenna, cheese.**

CHEMICAL BINDING EFFECT. The dependence of the neutron **cross sections** of a material on the chemical binding of the atoms composing the material

CHEMICAL PASSIVITY. See **passivity, chemical.**

CHEMILUMINESCENCE. **Luminescence** produced by chemical action.

CHEMISORPTION. See **adsorption, types of.**

CHI. Specific magnetic susceptibility (χ).

CHIEF RAY. The ray which passes through an optical system so as to intersect the axis at the plane of the aperture stop is called the chief ray.

CHILD-LANGMUIR-SCHOTTKY EQUATION. See **perveance.**

CHLORINE. Nonmetallic element, gaseous at ordinary temperature. Symbol Cl. Atomic number 17.

CHOKE COIL. This term is applied to various types of inductances used in electrical circuits primarily to present high reactance at certain frequencies. Such coils usually have high reactance compared to their resistance and offer impedance to the flow of alternating currents by the induced counter electromotive force. Since this **impedance** will vary directly with frequency the choke may be designed to let certain lower frequencies through and stop or impede higher ones. An air-core choke coil is often used in electrical power circuits to block high-frequency transients produced by lightning surges. In communications circuits air-core chokes are used extensively to block radio frequencies from audio-frequency circuits or from d-c parts of the circuit. In these applications they are often called radio-frequency chokes. Iron-cored chokes are frequently used in audio circuits in a similar manner. Iron-cored chokes are also important components of power supply filters as well as many wave **filters.**

CHOKE-INPUT FILTER. See **filter, choke-input.**

CHOPPER. (1) A device, usually mechanical, to impart a pulsating characteristic to a current or a beam of light by a regular and frequent interruption. (2) A device which modulates a signal by opening and closing contacts periodically. The frequency of the chopper is usually greater than any frequency of interest in the signal. (See **amplifier, chopper.**)

CHRISTMAS-TREE PATTERN. The optical pattern observed on a laterally-recorded phonograph record when its surface is illuminated by a light beam which is nearly parallel to its surface. The width of this pattern may be used to determine the frequency response of the record.

CHRISTOFFEL THREE-INDEX SYMBOL. One of certain quantities used in **tensor analysis.** They are not tensors themselves but they do involve the components and derivatives of tensors. They are of two kinds, often distinguished by brace and bracket, respectively:

$$\{mn,q\} = \frac{1}{2} g^{qs} \left(\frac{\partial g_{ms}}{\partial x^n} + \frac{\partial g_{ns}}{\partial x^m} - \frac{\partial g_{mn}}{\partial x^s} \right)$$

$$[mn,q] = \frac{1}{2} \left(\frac{\partial g_{mq}}{\partial x^n} + \frac{\partial g_{nq}}{\partial x^m} - \frac{\partial g_{mn}}{\partial x^q} \right)$$

where g_{mn} is a **symmetric covariant tensor,** $g^{qs} = G^{mn}/g$, with g the **determinant** of the components of g_{mn} and G^{mn} the **cofactor** of g_{mn} in g. From the definitions, it follows that

$$\{mn,q\} = g^{qs}[mn,s]$$

CHROMA (MUNSELL CHROMA). The dimension of the Munsell system of color which corresponds most closely to **saturation.** Chroma is frequently used, particularly by English writers, as the equivalent of **saturation.**

CHROMA CONTROL. In color television, the **gain control** which determines the amount of color signal fed to the demodulators. Setting this control to zero reduces the picture to black and white.

CHROMATIC ABERRATION. The failure of all the light from one point of an object to form an image at a point because of the dispersion of the material of the lenses. The focal length of a lens is, in general, greater for red light (longer wavelength) than for blue light (shorter wavelength). Systems consisting entirely of reflection optics do not show chromatic aberration. Hence, reflection optics are used extensively in infrared instruments. With compound lenses a proper choice of kinds of glass and of lens curvatures can partially compensate for chromatic aberration over a not-too-large wavelength region.

CHROMATIC ABERRATION, LONGITUDINAL. See **longitudinal chromatic aberration.**

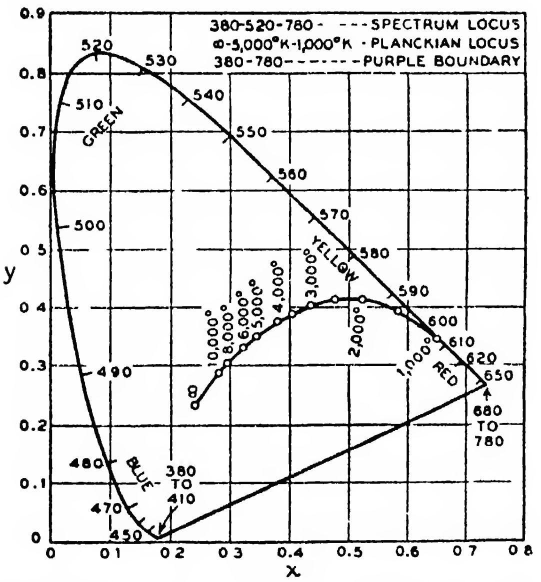
CHROMATICITY. The color quality of light definable by its **chromaticity coordinates,** or

by its **dominant** (or **complementary**) **wavelength** and its **purity** taken together.

CHROMATICITY, COMPLEMENTARY. The property of two light samples whereby they produce an **achromatic** visual stimulus when combined in suitable proportions.

CHROMATICITY COORDINATE. The ratio of any one of the **tristimulus values** of a sample to the sum of the three tristimulus values. The sum of the three chromaticity coordinates is always unity, so any two of them determine the **chromaticity.**

CHROMATICITY DIAGRAM. A plane diagram formed by plotting one of the three **chromaticity coordinates** against another. The most common chromaticity diagram at present is the CIE (x,y) diagram plotted in rectangular coordinates (see figure).



CIE (x,y) chromaticity diagram plotted in rectangular coordinates

CHROMATICNESS. The two attributes of visual sensation, **hue** and **saturation,** taken together; as distinguished from **brightness.**

CHROMATOGRAPHIC ADSORPTION. The application of the **adsorption** of solutes from solution. A solution is poured down a column packed with the powdered adsorbing material. The most readily adsorbed constituent of the solution will be adsorbed first, and the other constituents further down the column. This results in a partial separation of the mixture giving a "chromatogram." Pure solvent is then passed down the column to "develop" the chromatogram, and a better separation of the constituents is obtained.

Originally the method was used for colored substances, but it has now been adapted for colorless substances. Furthermore, many other means of adsorption have been developed; for example, filter paper.

CHROMATRON. A **kinescope** for color television.

CHROMINANCE. The colorimetric difference between any color and a reference color of equal **luminance,** the reference color having a specified **chromaticity.** In N.T.S.C. transmission, the specified chromaticity is the zero subcarrier chromaticity.

CHROMINANCE CHANNEL. In a color-television system, any path which is intended to carry the carrier color signal.

CHROMINANCE CARRIER REFERENCE. A **synchronizing signal** for television transmitters and receivers of the same frequency and phase relationship as the **chrominance** subcarrier in the **color burst** signal.

CHROMIUM. Metallic element. Symbol Cr. Atomic number 24.

CHROMOPHORE. Certain groups of atoms in an organic compound cause characteristic absorption of radiation irrespective of the nature of the rest of the compound. Such groups are called chromophores or color carriers.

CHROMOPHORIC ELECTRONS. Electrons in the double bonds of the chromophoric groups. Such electrons are not bound as tightly as those of single bonds and can thus be transferred into higher energy levels with less expenditure of energy. Their electronic spectra appear at frequencies in the visible or near ultraviolet region of the spectrum.

CHROMOSCOPE. An apparatus for measuring color values and intensities.

CHRONOGRAPH. An instrument for writing time. In the usual type of instrument a drum carrying a sheet of paper is rotated by clockwork at the rate of 1 rpm. A pen, attached to the armature of an electromagnet, is carried parallel to the axis of the drum by a screw and rests on the paper, tracing a spiral line. The electromagnet is connected in an

electric circuit with a standard clock in such a manner that every second the pen makes a short lateral movement which graduates the spiral line into seconds. A key is connected in the circuit in such a manner that each time the key is closed an extra graduation is made on the spiral. When the sheet is removed from the drum a scale may be used to measure the distance of the marks made by pressing the key from the marks made by the clock. In this way the time of pressing the key may be readily measured to 0.01 of a second. Where observation times are required with greater accuracy, the drum may be rotated more rapidly and a tuning fork used to make the time graduations. Other types of chronograph use a steadily moving strip of paper on which the pen traces its record. On the printing type of instrument a set of type wheels is rotated by a standard clock and each time a key is pressed a piece of paper is pressed against the type and the instant printed to the nearest hundredth of a second. Chronographs have many uses, for example, in apparatus designed to record vibrations from earthquakes.

CHRONOMETER. For many types of field observing where accurate time is required, the use of the pendulum clock is not practicable. This is particularly true on shipboard or in countries like Japan, where earthquakes frequently disturb the pendulum. The chronometer is an accurate type of escapement timekeeper which is spring driven. The movement is similar to that in the ordinary pocket watch but much more massive. Various devices to compensate for changes in temperature and for changes in the tension of the spring are incorporated in the instrument. When properly handled, the rate of a chronometer may be relied upon to within a few hundredths of a second per day. With modern methods of obtaining clock comparisons by radio at frequent intervals, the chronometer may be used for all except the most refined astronomical observations. Many chronometers are equipped with devices for making or breaking an electric circuit so that they may be used in conjunction with the **chronograph.**

CHRONOSCOPE. (1) An instrument for measuring time. (2) An electronic device for measuring extremely-short time intervals.

CHRONOTRON. (1) A device which utilizes a measurement of the position of the superposed loci of a pair of **pulses** on a transmission line to determine the time between the events which initiate the pulses. (2) A trade name for a time-delay device.

CIE. Abbreviation for "Commission Internationale de l'Eclairage" (International Commission on Illumination).

CIRCLE. A plane curve such that all of its points are at a fixed distance, its **radius,** from a fixed point, its **center.** Its general equation in rectangular coordinates is given by

$$x^2 + y^2 + 2Ax + 2By + C = 0$$

provided $D = A^2 + B^2 - C$ is positive and does not vanish. Under these circumstances, the radius of the circle is $\sqrt{D}$ and its center is at $x = -A$, $y = -B$. If $D = 0$, the circle degenerates into a point; if D becomes negative the circle is imaginary.

If the equation is transformed to new axes parallel to the original axes and the origin so chosen that terms in x and y are eliminated, the standard equation of the circle becomes

$$x^2 + y^2 = r^2$$

where r is its radius.

CIRCLE OF CONFUSION. Due to imperfect imagery and to the fact that the images of points at different object distances are commonly observed on a single image-plane (e.g., the film in a camera), the image of a point object is, in general, a small circle, the circle of confusion.

CIRCLE OF CONVERGENCE. The boundary of the region of the complex plane in which a **Taylor series** converges. For a given function, the radius of the circle of convergence depends on the point (center of the circle) about which the series is developed. On the boundary the power series **diverges** because of one or more **singular points.** Frequently the function may be found outside of the circle of convergence by **analytic continuation.**

CIRCUIT. A **network** providing one or more closed paths.

CIRCUIT, ALTERNATING CURRENT. See **alternating current circuits.**

CIRCUIT, ASTABLE. See **astable.**

CIRCUIT, BALANCED. A **circuit,** all of whose **impedors** are symmetrically disposed with respect to objects at ground potential.

CIRCUIT, BISTABLE. See **bistable.**

CIRCUIT, CLAMPING. Another name for a **d-c restorer.** (See **clamping.**)

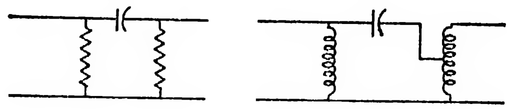
CIRCUIT, CLIPPING. A term with three possible meanings as follows: (1) A circuit for preventing the peak amplitude of an electrical signal from exceeding a predetermined level. (2) A circuit for eliminating the tail of an electrical pulse after a predetermined time. (3) A circuit element in a **pulse amplifier** for reducing the amplification at frequencies below a predetermined frequency

CIRCUIT, COINCIDENCE. See **coincidence circuit.**

CIRCUIT, COMBINER. A **mixing amplifier** in a color-camera chain which combines the **luminance** and **chroma** channels with the **synchronizing signals.**

CIRCUIT, CONTROL. See **control circuit.**

CIRCUIT, COUPLED. While any group of circuits which are so connected or related that effects in one produce effects in the other constitute a coupled circuit, the term is usually used to designate circuits related so a-c effects are transferred but steady state d-c effects are not The two most common classifications of coupled circuits are the inductive and the capacitive coupled circuits, so named because of the primary method of transferring the effects Capacitance coupling is used quite extensively in various vacuum tube amplifier circuits, in thyratron circuits, and similar applications where it is desired to block d-c effects and transfer a-c Since the **condenser** does this it may be used as the common element between the two circuits. The so-called resistance coupled amplifier is really capacitance coupled. Fig. 1 shows examples of this type. Inductive coupling is the most widely used type since it is used extensively in the power field as well as in the communications and electronics fields. The ordinary power **transformer** is the means of inductively coupling two power circuits. The various transformers, tuning coils, etc., of radio circuits are other examples. Fig. 2 shows some typical circuits.



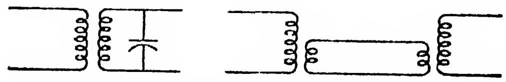


Fig 1. Capacitance coupled circuits (top)
Fig 2 Inductance coupled circuits (bottom)

CIRCUIT, DELAY. See **delay circuit.**

CIRCUIT, DIRECT CURRENT. See **direct current circuits.**

CIRCUIT, DOUBLER. See **doubler circuit.**

CIRCUIT, ECCLES-JORDAN. The name frequently applied to a **trigger circuit** or **bistable multivibrator.**

CIRCUIT, ELECTRIC. An **electric network,** providing one or more closed paths.

CIRCUIT (ISOLATED), ENERGY OF. The energy of an isolated circuit is $\frac{1}{2}LI^2$. (See **energy of a system of circuits.**)

CIRCUIT EQUATION. See **Kirchhoff laws.**

CIRCUIT, FLIP-FLOP. Another name for a **monostable** circuit.

CIRCUIT, FORCE ON A RIGID. See **force on a rigid circuit.**

CIRCUIT, FREE-RUNNING. Another name for an **astable** circuit.

CIRCUIT, GYRATOR. A circuit element which is so named because it violates the **reciprocity theorem** as does the **gyroscope.**

CIRCUIT, INTEGRATING. A circuit whose output current or voltage is proportional to the time integral of its input current or voltage. An example is a series circuit consisting of a resistor R and a capacitor C. If an input voltage V_i is applied across this circuit, the output voltage V_0 across the capacitor is

$$V_0 = \frac{1}{R}\int_0^t V_i dt, \text{ for times } t \ll CR$$

CIRCUIT, LOGARITHMIC DECREMENT OF. An exponentially-decaying **oscillation,** $Ae^{-\alpha t} \cos \omega t$, has the logarithmic decrement $\sigma / f = 2\pi\sigma/\omega$, the decay constant per cycle.

CIRCUIT, MAGNETIC. See **magnetic circuit.**

CIRCUIT, MONOSTABLE. See **monostable.**

CIRCUIT, NATURAL FREQUENCY OF. A simple tuned-circuit will respond to an impulse by ringing, or produce an exponentially-decaying, sinusoidal oscillation. The frequency of this oscillation is the natural frequency of the circuit. It is given by

$$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}},$$

for a circuit composed of a resistance R, an inductance L and a capacitance C, all connected in series. Circuits of greater complexity may often be reduced to an equivalent series circuit, although some may have more than one natural frequency and hence constitute coupled oscillators.

CIRCUIT, NATURAL OR FREE PERIOD OF. The reciprocal of the natural frequency of the circuit. (See **circuit, natural frequency of.**)

CIRCUIT, NEUTRALIZATION. An amplifier with an inductive output impedance will have an input **admittance** which consists of a negative **conductance** plus a positive **susceptance.** This fact means that some of the output power is fed back into the input circuit in such a phase relation that there is a component of input current 180° out of phase with the input voltage. This will cause **regeneration,** or perhaps **oscillation,** if the effect is sufficiently large. The negative input conductance of an amplifier can be overcome by the expedient which is known as the neutralization of the effect of the grid-to-plate capacitance. Neutralization is accomplished in one method by obtaining a voltage in the output circuit that is 180° out of phase with the plate-to-cathode potential, and impressing this voltage on the grid of the tube through a capacitor about equal in value to C_{gp}; thereby a current is impressed in the input circuit in phase with the input voltage. When the current so produced is just equal to that caused by the grid-to-plate capacitance C_{gp} of the tube, the neutralization is complete.

CIRCUIT, PHANTOM. See **phantom circuit.**

CIRCUIT, PHASE-SHIFTING. Any circuit containing resistive and reactive components used to produce a desired difference between the **phase** of the output voltage or current and the input voltage or current at some desired frequency.

CIRCUIT, PRINTED. See **printed circuit.**

CIRCUIT, PUSH-PULL. See **push-pull circuit.**

CIRCUIT, QUASI-BISTABLE. An **astable** circuit which is triggered at a rate that is high as compared with its own natural frequency.

CIRCUIT, QUASI-MONOSTABLE. A **monostable** circuit triggered at a rate which is high as compared with its own natural frequency.

CIRCUIT, QUENCHING. A circuit which diminishes, suppresses or reverses the voltage applied to a **counter tube** in order to inhibit multiple discharges from a single **ionizing event.**

CIRCUIT, REACTANCE TUBE. A circuit in which the effective reactive component is made dependent upon the **amplification** of an electron tube, and thus made subject to variation for control purposes. For example, the input capacitance of an electron tube in a grounded cathode circuit is commonly given as

$$C_{\text{input}} = C_{gk} + C_{gp}(1 + A)$$

where C_{gk} is the grid-to-cathode capacitance, C_{gp} is the grid-to-plate capacitance, and A is the amplification of the tube, which is assumed to be a real number. Variation of A by manipulation of the **bias** or some other parameter thus changes the **effective capacitance.**

CIRCUIT, RECORDING. A circuit which produces an impulse capable of operating some mechanical counting or recording device.

CIRCUIT, SCALE-OF-TWO. Another name for **bistable** circuit or Eccles-Jordan trigger circuit.

CIRCUIT, SCRAMBLER. A circuit, usually consisting of a balanced **modulator** and appropriate **filters,** for the production of scrambled or **inverted speech.**

CIRCUIT, SEPARATION. A circuit which will separate signals having different properties, such as amplitude, frequency, etc.

CIRCUIT, SHADING. A system of six waveform generators used to neutralize spurious signals produced by certain television camera tubes. To a certain extent these waveforms may also be employed to compensate for deficiencies in the uniform distribution of studio light. The shading unit generates three waveforms for vertical scanning and three more for horizontal scanning. These three signals for each axis consist of (1) sawtooth signals of either positive or negative polarity and variable in amplitude, (2) sine-wave signals adjustable in phase and amplitude, and (3) parabola signals available in either positive or negative polarity and adjustable in amplitude.

CIRCUIT, SIMPLEXED. See **simplexed circuit.**

CIRCUIT, SMEARER. A **circuit** sometimes used in **pulse amplifiers** to eliminate overshoot. Since it is basically an amplifier circuit with a short charging time and a relatively low discharge time, the overshoot is eliminated at the expense of having to tolerate a relatively-long trailing edge.

CIRCUIT, TANK. See **tank circuit.**

CIRCUIT, TIME CONSTANT OF A. The time required for the current in a circuit, or the potential difference across some element of the circuit to reach $1 - 1/\epsilon$ or about 63% of its final value after having had a step-function signal applied.

CIRCUIT, VOLTAGE-DOUBLER. See **voltage doubler.**

CIRCUIT(S), VOLTAGE SUPPLY AND REGULATOR. Any of a large number of circuits whose function is to provide d-c voltage for use as plate and filament supply voltage. Regulated supplies maintain the output voltage essentially constant under conditions of varying output current and or line voltage.

CIRCULAR ELECTRIC WAVE. See **wave, circular electric.**

CIRCULAR FUNCTION. A **trigonometric function.**

CIRCULAR MAGNETIC WAVE. See **wave, circular magnetic.**

CIRCULAR MIL. A unit of area, employed to designate the cross-sectional area of electrical conductors. It replaces measurement in square inches, and is more convenient since it is not necessary to multiply by the factor π. A mil is 1/1000 of an inch. The area of a circle whose diameter is M mils is simply M^2 circular mils.

Wires are sized by their area in circular mils or by the American wire gauge. Despite the arguments in favor of one system using diameters in mils as size numbers, the American wire gauge is commonly used for wires sized from 40 to 0000 American wire gauge. Wires larger than 0000 (212,000 circular mils) are always sized in circular mils.

CIRCULAR SCANNING. See **scanning, circular.**

CIRCULARLY-POLARIZED LIGHT. Discussed under **light, elliptically-polarized.**

CIRCULARLY POLARIZED SOUND WAVE. See **sound wave, circularly polarized.**

CIRCULATING MEMORY. In computer work, a memory consisting of a means for delaying information, and means for regenerating and reinserting the information into the delaying means.

CIRCULATING SIGNAL. A transmitted signal which travels one or more times around the earth.

CIRCULATION. The circulation around a closed path of any vector field is the line integral of that vector around the path. The vector ordinarily considered is the flow velocity, and the circulation is

$$K = \oint \mathbf{v} \cdot d\mathbf{s}$$

where $\mathbf{v}$ is the flow velocity, and $d\mathbf{s}$ is a vector element of the path. If the flow is irrotational, the circulation is zero around any path that can be contracted to zero without passing outside the fluid in the process. In a **barotropic fluid,** the circulation around any path moving with the fluid remains constant. (See **curl (of a vector); rotation (of a vector); Stokes theorem.**)

CIRCULATION OF THE ATMOSPHERE. See **atmosphere, circulation of.**

CIRROCUMULUS. Small billowed **cirrus**-type **cloud** composed of ice crystals. This type cloud indicates some instability in the layer at and above the cloud level which permits rising currents to form the cloud parcels and descending currents to create clear spaces between them. Cirrocumulus frequently occurs in advance of a cyclonic storm.

CIRROSTRATUS. **Cloud** veil of more or less uniform texture composed of ice crystals and therefore, like cirrus, lying entirely above the freezing level. Cirrostratus varies from white to gray, is usually translucent, and partially obscures the sun and moon. There are no shadows but often mock-suns or mock-moons which are images of the real celestial bodies. Cirrostratus often heralds the approach of a cyclonic storm, particularly in the temperate zone.

CIRRUS. High **cloud** composed of ice crystals and, therefore, lying entirely above the freezing level. Cirrus is never lower than about 4 miles in the tropics, but may be near ground levels in the polar areas. In appearance they are usually thin, wispy, often in streaks, and always whitish without shadows. Cirrus often forerun storms but not all cirrus are associated with storms. They cannot be used as a foolproof indication that a storm is approaching until considerable experience in cloud observation is attained.

CIRRUS, FALSE. See **false cirrus.**

CLAIRAUT EQUATION. A first-order **differential equation**

$$y = xp + f(p)$$

where $p = dy/dx$. Its general solution is $y = cx + f(c)$. It also has a solution obtained by elimination of p from the equations

$$y = px + F(p); \quad x + F'(p) = 0.$$

Since no arbitrary constant is involved in the latter case, the result is a **singular solution.**

CLAMPED DIELECTRIC CONSTANT. See **dielectric constant, clamped.**

CLAMPING. The connection of some point of a circuit to a desired reference potential for certain periods of time. Sometimes called d-c restoration.

CLAPEYRON-CLAUSIUS EQUATION. A fundamental relationship between the temperature at which an inter-phase transition occurs, the change in **heat content** and the change in volume, of the form:

$$\frac{dp}{dT} = \frac{\Delta H}{T\Delta V},$$

in which p is the pressure, T the temperature, dp/dT the rate of change of pressure with temperature, ΔH the change in heat content and ΔV the change in volume.

When applied specifically to the evaporation of liquids, this equation becomes

$$\frac{dp}{dT} = \frac{L}{T(V_2 - V_1)},$$

in which dp/dT is the rate of change of vapor pressure with temperature, L is the **molar heat of evaporation,** T is the temperature, and V_2 and V_1 are the molar volumes of vapor and liquid, respectively.

CLAPP OSCILLATOR. See **oscillator, Clapp.**

CLASS. As defined in **group theory.** (See **transform.**)

CLASS-A AMPLIFIER. See **amplifier, class-A.**

CLASS-A MODULATOR. See **modulator, class-A.**

CLASS-AB AMPLIFIER. See **amplifier, class-AB.**

CLASS-B AMPLIFIER. See **amplifier, class-B.**

CLASS-B MODULATOR. See **modulator, class-B.**

CLASS-C AMPLIFIER. See **amplifier, class-C.**

CLASS I STATION. A clear channel broadcast station with an operating power of not less than 10 kilowatts and not more than 50 kilowatts. It is designed to render both primary and secondary service at relatively long distance.

CLASS II STATION. A clear channel broadcast station designed to operate over a primary service area. Its operating power is between 0.25 and 50 kilowatts.

CLASS III STATION. A regional standard broadcast station designed for a primary service area. A Class III-A station operates on a power level between 1 and 5 kilowatts while a Class III-B station operates with a power level between 0.5 and 1 kilowatt at night, and not in excess of 5 kilowatts during daylight hours.

CLASS IV STATION. A local service broadcast station with an operating level not less than 0.1 kilowatt or greater than 0.25 kilowatt.

CLASSICAL. The adjective "classical" is in general applied to any physical theory or treatment that is based on the assumption of Newtonian mechanics. Such treatments include all electrical and magnetic discussions based on the **Coulomb law,** the **Ampere law,** and the **Maxwell equations.** Classical theory is usually to be distinguished from **relativity** theory and **quantum theory,** although relativistic treatments not involving the quantum hypothesis are occasionally referred to as classical, as are treatments involving quantum theory but not **quantum mechanics.**

CLASSICAL APPROXIMATION. See **Wentzel-Kramer-Brillouin approximation.**

CLASSICAL SCATTERING CROSS SECTION. See **Thomson scattering.**

CLAUDE METHOD. See **low temperature.**

CLAUSIUS EQUATION. A form of the **equation of state,** relating the pressure, volume, and temperature of a gas, and the gas constant. The Clausius equation applies a correction to the **van der Waals equation** to correct the pressure-correction term a for its variation with temperature. The Clausius equation takes the form

$$\left[P + \frac{a}{T(V + c)^2}\right](V - b) = RT$$

in which P is the pressure of the gas, T is the absolute temperature, V is the volume, R is the **gas constant,** b is a constant, a is a temperature-dependent constant, and c is a function of a and b.

CLAUSIUS LAW. The **specific heat** of an **ideal gas** at constant volume is independent of the temperature.

CLAUSIUS-MOSOTTI EQUATION. The relation between the **dielectric constant** k and the **polarizability** α of the individual molecules of an assembly containing N such molecules per unit volume:

$$\frac{k - 1}{k + 2} = \frac{4\pi}{3} N\alpha = \frac{\rho}{M} P_M$$

where ρ/M is the ratio of density to molecular weight, and P_M is the molar polarization of the substance.

CLAYDEN EFFECT. A photographic effect discovered by A. W. Clayden (1900). A photographic material which is first given a partial exposure to diffuse light, produces a reversed image if exposed a second time to a brilliant source of light. The effect is observed frequently in photographing lightning. If the lens is left open to await a flash in the proper position, other flashes occurring in the meantime (street lights, etc.) produce a general exposure. Then when a brilliant flash occurs the shutter is closed and the image developed. The image of the flash may develop as a positive or as a negative depending upon the relation of the two exposures. The term "black lightning" is also applied to this phenomenon.

CLEANUP. (1) The removal of gas from a high-vacuum tube by the action of the **getter.** (2) The gradual disappearance of gas in a discharge tube (such as a cold cathode-ray tube or an x-ray tube) due to absorption by the electrodes and glass walls.

CLEAR (VERB). To restore a storage or memory device to a prescribed state, usually that denoting zero.

CLEBSCH-GORDAN COEFFICIENTS. Coefficients $C_{jj'}(JMmm')$ in

$$\mathcal{Y}^M_{Jjj'} = \sum_{m=-j}^{j} \sum_{m'=-j'}^{j'} C_{jj'}(JMmm')\mathcal{Y}_{jm}(1)\mathcal{Y}_{j'm'}(2)$$

where

$$J_z^{(1)}\mathcal{Y}_{jm}(1) = m\mathcal{Y}_{jm}(1),$$

$$J_z^{(2)}\mathcal{Y}_{j'm'}(2) = m'\mathcal{Y}_{j'm'}(2).$$

$$\{J^{(1)}\}^2\mathcal{Y}_{jm}(1) = j(j + 1)\mathcal{Y}_{jm}(1),$$

$$\{J^{(2)}\}^2\mathcal{Y}_{j'm'}(2) = j'(j' + 1)\mathcal{Y}_{j'm'}(2)$$

and

$$\{J_z^{(1)} + J_z^{(2)}\}\mathcal{Y}^M_{Jjj'} = M\mathcal{Y}^M_{Jjj'} \quad (M = m + m')$$

$$\{J^{(1)} + J^{(2)}\}^2\mathcal{Y}^M_{Jjj'} = J(J + 1)\mathcal{Y}^M_{Jjj'},$$

the operators $J^{(1)}$, $J^{(2)}$ being vector **angular momentum operators.**

CLERK MAXWELL RELATION. According to Clerk Maxwell's identification of light with **electromagnetic radiation,** the **dielectric constant,** k, and the **refractive index,** n, of a substance should be related by the formula $k = n^2$. This relation only holds under rather restrictive conditions, such as the absence of permanent **dipoles** in the substance, measurement with light of very long wavelength, etc.

CLICK FILTER. See **filter, click.**

CLICK GAUGE. A device used for the measurement of moderate pressures, employing a thin diaphragm which has two stable positions. The diaphragm separates the system in which the pressure is to be measured from a system in which the pressure can be controlled. Slight differences in pressure on the two sides are indicated by an audible "click" sound as the diaphragm moves from one stable position to the other.

CLIMATE. Average weather of any region. Averages need not be for a whole year but can be computed from data for months, weeks, or days. It is necessary that sufficient data be available to remove the element of irregularity from climatic values.

CLIMATE, CONTINENTAL. See **continental climate.**

CLIMB. The motion of an **edge dislocation** normal to its **slip plane.** This process requires the movement of **vacancies** to or from the extra half plane of the dislocation, and hence its rate is governed by **diffusion.**

CLINOMETER. An instrument for measuring the angle of elevation of clouds, balloons, etc., in meteorology. It consists of a telescope with cross-wires, mounted on a divided quadrant from which the elevation may be read.

CLIPPER. In communications, a circuit which does not permit the positive (or negative) level of signal to exceed a certain value. The most extensive use of clippers in television receivers is the separation of the sync pulses from the rest of the video signal.

CLIPPER LIMITER. A **transducer** which gives output only when the input lies above a critical value, and a constant output for all inputs above a second higher critical value. This is sometimes called an amplitude gate, or slicer.

CLIPPING. The process performed by a **clipper.**

CLIPPING CIRCUIT. See **circuit, clipping.**

CLIPPING TIME. The time constant of the clipping circuit. (See **circuit, clipping (2) and (3).**)

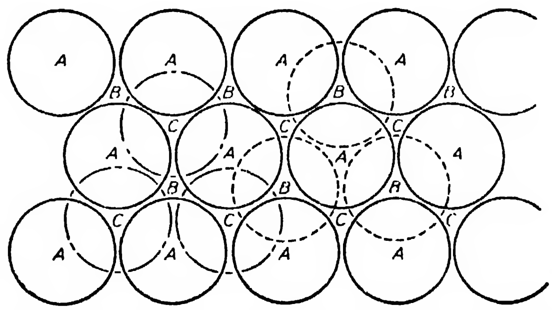
CLOCK. See **time.**

CLOCK PARADOX. If two identical clocks A, B, are synchronized and then A is accelerated arbitrarily and then brought back to compare with B, which has not been accelerated, then A will record a shorter time interval than B. This conclusion is a consequence of, and is understandable in terms of, **relativity theory.**

CLOCKSPRING CORE. One of the names applied to a toroidal core made up of a thin magnetic tape wound into the form of a ring.

CLOSE-PACKED, HEXAGONAL. A common form of **crystal structure** in which plane triangular nets of atoms are stacked on one another in the order ABAB ···. (Cf. **close-packed structure.**)

CLOSE-PACKED STRUCTURE. A type of **crystal structure** obtained by arranging equal spheres so that they occupy the minimum



Stacking spheres in close packing. When one closed pack layer has been laid down (the A layer), the next layer can go into either of the two sets of hollows (B or C) on the first layer. A, B, and C denote the centers of the spheres in the three possible positions. (By permission from "Dislocations in Crystals" by Read, Copyright 1953, McGraw-Hill Book Co., Inc.)

volume. Two such structures are possible, **face-centered** cubic and **close-packed hexagonal.** They may be realized by stacking tri-

angular plane networks of spheres on one another so that the atoms in one layer fit into the spaces in the one below. If the three types of layers have atoms lying above points A, B, C, respectively, then the layers are stacked in the order ABCABC ··· in the face-centered structure, and ABAB ··· in the hexagonal structure.

CLOSE-TALKING MICROPHONE. See **microphone, close-talking.**

CLOSED INTERVAL OR SET. A **set** which includes the bounding points as members of the **set.**

CLOSED LOOP. Portion of a **Feynman diagram** describing the virtual creation of a number of electron-positron pairs together with the annihilation of all of them, as for example in the scattering of light by light

CLOSED SYSTEM. A system which is isolated from its surroundings, and which may therefore reach a state of thermodynamic equilibrium, i.e., a time-invariant state where all macroscopic quantities remain unchanged and no spontaneous processes occur. (See also **non-equilibrium thermodynamics** and **closed system.**)

CLOUD. Large numbers of water droplets or ice crystals virtually suspended in the atmosphere. Actually the water or ice in a cloud occupies only a small fraction of the total space appearing as a cloud Light well reflected from the droplets or crystals and the cloud body appears as an opaque drifting object. Clouds can be classified in several ways. The two most common are in regard to form, stratified or billowed; and in regard to height, high, medium, or low The basic cloud forms are internationally recognized but there are many variations of each form.

CLOUD CHAMBER. An enclosure containing air or other gas saturated with water vapor, the cooling of which by a sudden expansion results in the formation of fog droplets upon particles of dust or other nuclei That **ions** in the gas are capable of serving as condensation nuclei, even when no dust is present, was demonstrated by the experiments of C. T. R. Wilson. Thus the clouds produced are much more dense if the gas is traversed by some ionizing emission like **x-rays or alpha rays.** Sir J. J. Thomson utilized this effect in his early measurements of the electronic charge. One of the most striking phenomena of the Wilson cloud chamber is exhibited when single ionizing particles such as alpha or beta particles, are allowed to traverse it just before the expansion. The path of each particle is marked by a visible white streak or "track" of mist, sometimes several cm in length which soon diffuses and disappears The study of photographs of such cloud tracks has in recent years afforded much information as to the nature and the movements of the particles producing them. (See also **cloud chamber, diffusion.**)

CLOUD CHAMBER, COUNTER-CONTROLLED. A **cloud chamber** whose expansion is triggered by a counter or counters, used for studying particular events.

CLOUD CHAMBER, DIFFUSION. A **cloud chamber** which utilizes the diffusion of vapor under the influence of a high temperature gradient to produce a supersaturated condition. The process is continuous, and it is not necessary to use repeated expansions, as in conventional cloud chambers.

CLOUD CHAMBER, HIGH-PRESSURE. A **cloud chamber** in which the gas is maintained at high pressure to reduce the range of high energy particles and so to increase the probability of observing events

CLOUD CHAMBER, LOW-PRESSURE. A **cloud chamber** in which the gas is maintained at low pressure to increase the range or decrease the scattering of particle tracks.

CLOUD, ICE-CRYSTAL. See **ice-crystal clouds.**

CLOUD POINT. The temperature at which a solution becomes cloudy as it is cooled at a specified rate. The cloud point is an important property in the specification of lacquers, oils, and other important solutions.

CLOUD-TRACK INTERPRETATION. Tracks are formed in **cloud chambers** by the condensation of vapor on the ionization produced by a particle traversing the chamber. The presence of the track indicates that the particle was charged; its density, length, curvature in a magnetic field, etc., may be interpreted so as to provide information on the sign and amount of charge, mass, energy, etc., of the particle.

CLUSIUS COLUMN. A device for the **separation of isotopes by thermal diffusion.** Two versions of this apparatus exist: in one the inner hot wall is an electrically heated wire; in the other it is a cylinder of diameter comparable to that of the outer cylinder. In the separation of liquids the annular space is only a small fraction of a centimeter wide, while in the separation of gases the space is of the order of a centimeter.

CLUSTER. A small group of liquid molecules with much the same spatial arrangement as in a solid crystal. Clusters are found in liquids for temperatures not far removed from the melting point.

CLUSTER, ION. See **ion cluster.**

CLUTTER. Radar echoes from stationary or slow moving objects.

COACERVATION. The production, by **coagulation** of a **hydrophilic sol,** of a liquid phase, which often appears as viscous drops, instead of forming a continuous liquid phase.

COAGEL. A gel formed by **precipitation** or **coagulation,** as distinguished from gel formed by swelling of a solid colloid.

COAGULATION. (1) The process of complete or partial solidification of a sol to a gelatinous mass; or of the separation from a liquid system of a gelatinous mass. It involves the separation of the disperse from the **continuous phase** which fact distinguishes it from "gelation." (2) The result of an alteration of a **disperse phase** or of a dissolved solid which causes the separation of the system into a liquid phase and an insoluble mass, as the coagulation of egg albumin. (3) The separation of a gelatinous mass from a liquid system, as the clotting of blood. Derived terms: coagulate; coagulator; coagulum.

COAGULATION VALUE. The concentration of a coagulant which effects a given amount of coagulation of a colloidal, or other dispersed system.

COATED CATHODE. An emissive structure which has been coated with certain elements or compounds to provide increased electron emission.

COATED LENSES. Lenses coated with low reflectance films.

COAXIAL ANTENNA. See **antenna, coaxial.**

COAXIAL LINE. A **transmission line** in which one conductor completely surrounds the other, the two being coaxial and separated by a continuous solid dielectric or by dielectric spacers with gas as the principal insulating material. Such a line is characterized by no external **field,** and by having no susceptibility to external fields from other sources. It is extensively used for radio-frequency transmission lines and is installed as a multichannel telephone **carrier** and television program line.

COBALT. Metallic element. Symbol Co. Atomic number 27.

CO-CHANNEL INTERFERENCE. See **interference, co-channel.**

COCHLEA. The inner ear, a bony structure of spiral form containing three parallel canals, one of which, the organ of Corti (see **Corti, organ of**) contains the nerve terminals which are stimulated by vibrations in the cochlea

COCHLEA PARTITION. The structure dividing the cochlea into two major parts. It is formed in part by the basilar membrane.

COCKCROFT-WALTON ACCELERATOR. A device in which rectified a-c voltage is used to charge a series of condensers to a high d-c potential, which is then applied to the acceleration of charged nuclear particles, especially **protons.**

COCKCROFT-WALTON EXPERIMENT. The first successful nuclear disintegration produced by artificially accelerated protons (1930). The reaction involved was interpreted as the formation of two α-particles from the combining of the proton and the lithium isotope of mass 7. This can be represented by an equation as

$$_1H^1 + {}_3Li^7 \rightarrow {}_4Be^8 \rightarrow 2{}_2He^4 + Q$$

where Q represents the kinetic energy of the α-particles in excess of the kinetic energy of the incident proton.

CODAN. Abbreviation for carrier operated device, anti-noise. A device which silences a **receiver** except when a modulated carrier signal is being received.

CODDINGTON EYEPIECE. An eyepiece made from a single piece of glass with a groove cut around its equator to act as a stop.

The two convex surfaces are portions of the same sphere. Probably first made by Sir David Brewster.

CODDINGTON SHAPE AND POSITION FACTORS.

Shape factor, $$S = \frac{r_2 + r_1}{r_2 - r_1}$$

where r_1 and r_2 are the radii of the first and second surface of a lens,

Position factor, $$P = \frac{q - p}{q + p}$$

where p and q are object and image distances.

The spherical aberration given in **Third order theory** may be expressed in terms of these two Coddington factors.

CODE. (1) A system of symbols and rules for use in representing information. (2) Loosely, the set of characters resulting from the use of code. (3) To express given information by means of a code. (See also **language.**)

CODE CHARACTER. A particular arrangement of **code elements** used in a **code** to represent a single value.

CODE ELEMENT. One of the discrete events in a **code**, such as the presence or absence of a **pulse**, or of a dot or a dash or space as used in a Morse code.

CODE, ERROR-CORRECTING. A code used in a redundant signal to improve the reliability of transmission at the expense of channel capacity.

CODER. A device which samples the modulating signal at regular intervals in a **pulse code modulation system.**

COEFFICIENT(S) OF AN AFFINE CONNECTION. The coefficients $\Gamma^{\mu}_{\iota\sigma}$, $\Gamma'^{\rho}_{\mu\iota}$, in the law of parallel displacement (see **affinely connected space**). The scalar product of two vectors remains constant under parallel displacement only if $\Gamma^{\mu}_{\nu\sigma} = \Gamma'^{\mu}_{\iota\sigma}$. When a metric is defined the coefficients $\Gamma^{\mu}_{\iota\sigma}$ become the **Christoffel three-index symbols.**

COEFFICIENT OF CONDENSATION. See **condensation, coefficient of.**

COEFFICIENT OF CONTRACTION. The ratio of the sectional area of the parallel jet of liquid issuing from an orifice to the area of the orifice. Its value depends on the nature of the orifice and varies between 0.5 and 1.

COEFFICIENT OF DISCHARGE. The ratio of the actual discharge through an orifice to the discharge computed by assuming uniform flow through the orifice with velocity $\sqrt{2gh}$, where h is the head causing the discharge. The coefficient depends on orifice shape, on the fluid viscosity and on many other factors.

COEFFICIENT OF EXPANSION. See **expansion.**

COEFFICIENT OF HEAT TRANSFER. See **heat transfer.**

COEFFICIENT OF RESTITUTION (COLLISION COEFFICIENT). In a two-body collision involving particles 1 and 2, moving in the same straight line, the coefficient of restitution is defined by

$$e = \frac{v_2 - v_1}{u_1 - u_2}$$

where $u_1 > u_2$ are the velocities with respect to a primary inertial system before collision and $v_2 > v_1$ are the corresponding velocities after collision. For a completely elastic collision $e = 1$. For an inelastic collision $e < 1$. (See **impact.**)

COEFFICIENT OF VELOCITY. The ratio of the mean flow velocity in a liquid jet to the theoretical velocity of discharge of a frictionless liquid, the latter being given by $\sqrt{2gh}$.

COERCIVE FORCE (H_c). The **magnetic field** at which the **magnetic induction** (B) is zero when the material is in a symmetrically, cyclicly magnetized condition. (Cf. **hysteresis, magnetic.**)

COERCIVE FORCE, DYNAMIC. That value of applied **magnetizing force** at which a major dynamic hysteresis loop crosses the abscissa axis (has zero value of magnetization). (Cf. **hysteresis, magnetic.**)

COERCIVE FORCE, INTRINSIC (H_{ci}). The **magnetizing force** at which the intrinsic induction (see **induction, intrinsic**) is zero when the material is in a symmetrically, cy-

clicly magnetized condition. (Cf. **hysteresis, magnetic.**)

COERCIVITY (H_{cs}). That property of a magnetic material which is measured by the **coercive force** when the cyclic state reaches saturation. (Cf **hysteresis, magnetic.**)

COFACTOR OF A DETERMINANT. The **complementary minor** to the element A_{ik} of a **determinant,** multiplied by the sign $(-1)^{i+k}$. Also called **signed minor.**

COHERENCE. See **coherent radiation,** and **interference.**

COHERENCE IN SOUND REVERBERATION. The occurrence of received sound **reverberation** in the form of pulses or short bursts.

COHERENT OSCILLATOR. See **oscillator, coherent.**

COHERENT RADIATION. In coherent radiation there are definite phase relationships between radiation at different positions in a cross section of the radiant energy beam (or beams), whereas in noncoherent radiation these relationships are random. For example, a slit is filled with approximately coherent radiation when it receives light from a small distant source, because every portion of the slit is then illuminated by the light from each radiating atom or molecule of the source. **Interference** bands are observed only between coherent beams.

COHERENT SCATTERING. See **scattering, coherent.**

COHESION. Forces between the particles of any given mass by virtue of which it resists physical disintegration. The connotation of the term cohesion implies a difference from adhesion, in which the forces are operative chiefly in surfaces. (See **cohesion, work of,** and see also **adhesion and cohesion.**)

COHESION PRESSURE. The addition term a/V^2 used in the **van der Waals equation** to correct the pressure by adding the attractive force of the molecules. V is the volume of the gas, and a is approximately constant for a given gas.

COHESION, WORK OF. The work required to separate a column of liquid 1 cm² in cross section into two. It is given by

$$W_c = 2\gamma_L$$

γ_L is the **surface tension** between liquid and vapor in ergs per cm².

COHO. A coherent oscillator (see **oscillator, coherent**) used with moving-target, indicator radar systems.

COIL. This term applies to one or more turns of conductor when wound as a definite unit of an electrical circuit. Thus we have the **choke coil,** or as it is sometimes called, impedance coil, as a number of turns of wire forming a coil used primarily for its reactance effect. The **transformer** is a unit of one or more coils used for transferring electrical energy by magnetic induction. Coils are particularly important in communications circuits where they serve in the above capacities, but also form parts of the tuned circuits which make possible our complex systems. While the coil is ordinarily used for its inductive properties, it inherently has both resistance and distributed capacity. The former is because of the resistance of the wire of which it is wound. The latter is due to the potential difference between turns which are separated by the turn insulation. At high frequencies this distributed capacity becomes extremely important and limits the usefulness of a given coil. Various special winding schemes have been used to minimize this effect. Electrical machines have coils as essential components, e.g., field coils, armature coils, etc.

COINCIDENCE (IN COUNTER TECHNOLOGY). The occurrence of **counts** in two or more detectors simultaneously or within an assignable time interval. A *true coincidence* is one that is due to the detection of a single particle or of several genetically related particles. An *accidental, chance,* or *random coincidence* is one that is due to the fortuitous occurrence of unrelated counts in the separate detectors. A *delayed coincidence* is the occurrence of a count in one detector at a short, but measurable, time later than a count in another detector, the two counts being due to a genetically-related occurrence such as successive events in the same nucleus.

COINCIDENCE, ANTI-. The occurrence, in a particular detector, of a **count** unaccompanied by a simultaneous count, or by a count within an assignable time interval, in one or more other specified detectors.

COINCIDENCE CIRCUIT. A circuit used for **coincidence counting.**

COINCIDENCE COUNTER. See **counter, coincidence.**

COINCIDENCE COUNTING. An experimental technique in which particular types of events are distinguished from background events by means of coincidence circuits so designed or employed as to register **coincidences** caused by the type of events under consideration.

COINCIDENCE METHOD. See **physical measurements.**

COL. A relatively small area about midway between two **cyclones** and two **anticyclones** where the pressure gradient is very weak and winds are usually light and variable. It is the point of intersection between a **trough line** and a **wedge line.**

COLD CATHODE. See **cathode, cold.**

COLD-CATHODE TUBE. See **tube, cold-cathode.**

COLD DOME. A moving mountain or mass of cold, dense air.

COLD FRONT. Any boundary surface separating cold air from warmer air, along which cold air is actively displacing the warm air.

COLD SECTOR. Temperate-zone **cyclones** usually involve two **air masses.** That part of the cyclone occupied by the cold air is known as the cold sector (in contrast with the area occupied by the warm air, which is the warm sector). Cold sectors constitute more than one-half, and often practically all the area covered by a cyclone.

"COLD TESTS" OF RESONANT SYSTEMS. The testing of a **microwave system** with the tube in place, but in a nonoperative condition so that its electronic admittance is zero The **resonance frequency,** loaded and unloaded **Q,** and the **driving point admittance** are quantities usually measured

COLD WAVE. A rapid and marked fall of temperature during the cold season of the year.

COLD WORK. Considerable **plastic deformation** of a metal at such a temperature that the material contains **strains, dislocations,** etc., in a metastable state.

COLLECTIVE ELECTRON THEORY OF FERROMAGNETISM. The electrons responsible for **ferromagnetism** are supposed to be more or less free. Parallel alignment of their spins is favored by the **exchange interaction.** With the introduction of **Fermi-Dirac statistics,** is is possible to show that a transition from the ferromagnetic to the paramagnetic state occurs at a certain temperature, which is identified with the **Curie point.**

COLLECTIVE MODEL OF ELECTRONS IN METALS. See **Bohm and Pines method.**

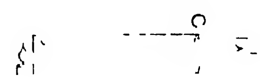
COLLECTOR. (1) In an **electron tube,** an electrode that collects electrons or ions that have completed their functions within the tube. (2) In a **transistor,** an electrode through which a primary flow of **carriers** leaves the **interelectrode** region.

COLLECTOR MULTIPLICATION (IN A TRANSISTOR). The increase in the number of collected **carriers** at an inversely-biased ***p-n* junction,** due to an excessive density of **minority carriers** in the collector region

COLLECTOR RESISTANCE, TRANSISTOR. See **transistor parameter r_c**

COLLIMATION. The process by which a divergent beam of energy or particles is converted into a parallel beam. (Cf. **collimator.**)

COLLIMATOR. (1) An optical apparatus for producing parallel rays of light. A common form consists of a converging **lens,** at one of whose focal points is placed a small source of light, usually a pinhole or narrow slit upon which light is focused from behind Rays



COLLIMATOR
Divergent rays from slit S rendered parallel by objective O

diverging from this focal point emerge from the objective **lens** in a parallel beam The slit or other source is viewed through the collimator without **parallax,** since it appears at an infinite distance. The arrangement is very generally used on **spectroscopes** and spectrometers. (2) By analogy, any arrangement of slits or apertures which limits a stream of

particles to a beam in which all the particles move in the same, or nearly the same, direction.

COLLIMATOR, FOCAL. See **focal collimator.**

COLLINEAR EQUATIONS (OPTICAL). If the intersection of the **optical axis** with a plane through the **principal focal point** of object space is taken as the origin of coordinates for points in the object space and a similar origin is taken for coordinates in image space, the following collinear equations result:

$$xx' = ff'$$

$$y'/y = f/x = x'/f'$$

where x, x' are distances from their respective origins parallel to the optical axis, y, y' are distances normal to the optical axis, and f, f' are focal distances measured from their respective origins.

COLLISION. As used in physics, this term refers to any interaction between free particles, aggregates of particles, or rigid bodies in which they come near enough to exert a mutual influence, generally with exchange of energy. It does not necessarily imply actual contact. The process is always subject to conservation of momentum, and in an "elastic collision," also to conservation of energy. In the latter case, if the initial velocities are given, the velocities of the bodies after collision can be calculated by applying these two conservation principles. The subject is of special significance in atomic physics, where a collision is defined as a close approach of two or more photons, particles, atoms or nuclei during which an interchange occurs of charge, energy, momentum or other quantities. (See also **impact.**)

COLLISION DENSITY. In nuclear technology, the number of neutron collisions with matter per unit volume per unit time. Partial collision densities may be defined for neutrons characterized by such parameters as speed and direction.

COLLISION DIAMETER OF MOLECULES. The distance of closest approach between the centers of any two molecules in a collision.

COLLISION, ELASTIC. A collision during which no change occurs in the internal energy of the participating systems; or in the sum of their kinetic energies of translation. The total mechanical energy is conserved, hence the **coefficient of restitution** is unity. (See also **impact.**)

COLLISION, INELASTIC. A collision during which changes occur both in the internal energy of one or more of the participating systems, and in the sums of their kinetic energies of translation before and after the collision.

COLLISION OF THE FIRST KIND. The collision of an accelerated particle (e.g., electron) with an atom resulting in a transfer of energy whereby the atom becomes excited and the electron is slowed.

COLLISION OF THE SECOND KIND. The collision of an excited atom with a slow particle (e.g., electron) whereby the atom undergoes transition to a lower energy state and the other particle is accelerated.

COLLISION, PERFECTLY INELASTIC. A collision during which the amount of mechanical energy converted into internal energy has the greatest possible value consistent with the conservation of momentum. In such a collision the **coefficient of restitution** is zero.

COLLISION, PLASTIC. A **collision** in which plastic deformation of one or both colliding particles takes place, and some mechanical energy is dissipated. The **coefficient of restitution** is less than unity. (See also **impact.**)

COLLISION WITH ELECTRONS, PROBABILITY OF. The number of collisions per unit **electron current** per unit path length per unit pressure at 0°C.

COLLOID. Noncrystalloid. Substances that form two-phase systems with **solvents** which exhibit the gross properties of solutions, or modifications of crystalline substances which are capable of forming such systems. The former view that the colloid is essentially different from substances which form true solutions is giving way to consideration that the **colloidal state** is merely a condition into which all, or nearly all, substances can be brought by suitable means. Colloidal "solutions" do not obey the solution laws: the alterations of the boiling and freezing points are inappreciable, and the osmotic pressures very small. A colloidal solution is, in reality,

a disperse system, and such measures as separate disperse systems will usually cause the **coagulation** and **precipitation** of colloids. Ostwald distinguished between two classes of colloidal liquids, one in which the suspended colloid does not sensibly affect the properties of the dispersive medium, such as suspensions of metals, metallic sulfides or clay; and the class in which the reverse is true as in the case of gelatin solutions which "set" to gels below a certain temperature. (See also **colloidal system.**)

COLLOID, HETEROPOLAR. A colloidal system in which the dispersed particles are **polar compounds.**

COLLOID, HOMOPOLAR. A colloidal system in which the dispersed particles are **nonpolar compounds.**

COLLOID, NEUTRAL. The colloidal system formed in soap solutions at high concentrations of soap The colloidal particles are crystalline in nature and possess a laminated structure consisting of layers of undissociated soap molecules.

COLLOID, REVERSIBLE AND IRREVERSIBLE. (1) A distinction based on the fact that certain substances immediately assume the colloidal state on contact with pure water. These are termed reversible colloids Others remain insoluble when once separated from the disperse system. There is no real theoretical distinction between the classes, for the phenomenon depends upon the velocity with which the disperse particles form grains of precipitable size, and all such "reversible" colloids eventually become irreversible. (2) Colloids which, like agar agar or gelatin, form both solutions and two phase systems with water according to temperature are termed reversible.

COLLOIDAL EQUIVALENT. A term applied to the **dispersed phase** of a colloidal system, denoting the number of molecules per unit electric charge.

COLLOIDAL SOLUTIONS, METHODS OF PREPARATION. Colloids fall roughly into two groups. First are the natural colloids, which are usually lyophilic, where the materials give colloidal solutions when they are put in a suitable dispersing medium or when they are warmed in this medium; for example, proteins or soaps in water. The second group, called artificial colloids, are usually lyophobic sols, and have to be prepared by special methods. These methods are grouped under dispersion or peptization processes in which particles or macroscopic dimensions are broken down to colloidal dimensions; and condensation or precipitation processes where the colloid is formed by building up from ions, atoms, or molecules

The main dispersion processes are (1) mechanical methods, such as the colloid mill, (2) electrical disintegration methods using an electric arc, (3) peptization and (4) ultrasonic waves.

In condensation processes where colloids are formed by the aggregation of atoms or molecules the stages are (1) formation of a supersaturated olution which can be brought about in a number of ways, such as **hydrolysis** reactions, double decomposition reactions, reductions, oxidations, and exchange of solvent; (2) formation of nuclei in the supersaturated solution; (3) growth of nuclei to larger particles until they reach colloidal dimensions.

COLLOIDAL STATE. A system of particles in a dispersing medium, in which the mean size of the particles lies between molecular size and a size great enough to be visible to the eye, or in the optical microscope. The size limits are approximately 2×10^{-5} cm to 5×10^{-7} cm

COLLOIDAL SYSTEM. A multiphase system in which there is at least one finely-divided dispersed phase more or less uniformly distributed through the continuous phase known as the dispersion medium. The size of the particles in the dispersed phase can be roughly between 2×10^{-5} cm and 5×10^{-7} cm The types of colloidal systems usually encountered, depending on the nature of the dispersed phase and the dispersion medium, are: sol, emulsion, foam, solid sol, solid emulsion, solid foam, solid aerosol, liquid aerosol, gel

COLOGARITHM. The **logarithm** of the reciprocal of a number. Sometimes used in logarithmic computation to avoid the use of negative **mantissas** or of subtraction of logarithms

COLOR. Color consists of those characteristics of light other than spatial and temporal inhomogeneities, light being defined here as that aspect of radiant energy of which a

human observer is aware through the visual sensations which arise from the stimulation of the retina of the eye. Color is a broad psychophysiological concept, embracing far more than the psychological sensation of hue. It includes the grays, as well as the chromatic colors; the characteristics of light constituting color may be stated in terms of the appropriate **photometric** quantity, **dominant wavelength** and **purity**—corresponding generally to the attributes of visual sensations, **brightness, hue** and **saturation.** (See also **Young-Helmholtz theory of color sensation.**)

COLOR ANALYZER, KEUFFEL AND ESSER. A visual **spectrophotometer** using a single **collimator** having a divided slit.

COLOR BLINDNESS. The inability of certain defective eyes to distinguish between different colors. Inability to distinguish between red and green is fairly common, particularly in men. Yellow-blue color blindness is much less common. With reduced illumination we all become color blind before we cease to see at all. This effect is due to the greater sensitivity of the rods, which are not color-sensitive, than the cones, which are color-sensitive.

COLOR BURST. That portion of the composite **color signal** comprising the few sine-wave cycles of color subcarrier frequency (and the **color burst pedestal,** if present) which is added to the horizontal pedestal for synchronizing the color-carrier reference.

COLOR-BURST PEDESTAL. See **burst-pedestal.**

COLOR CARRIER. See **color subcarrier.**

COLOR-CARRIER REFERENCE. A continuous signal having the same frequency as the color subcarrier and having fixed phase with respect to the **color burst.** This signal is used for the purposes of **modulation** at the transmitter, and **demodulation** at the receiver.

COLOR CENTER. When an alkali halide crystal is heated in an atmosphere of the alkali vapor, it takes on a deep color, which is attributed to the creation of **lattice vacancies,** acting as centers to which electrons are attracted. The color is due to the absorption of light in a broad band, as the electrons are ionized away from the center. By illumination in the absorption band, the color may be bleached, and the crystal rendered photoconducting (see **photoconduction**). Color centers may be produced in other ways than by heating in alkali vapor, such as by electrolysis, by irradiation with x-rays, electrons or neutrons, etc. Several types of color centers or bands have been designated, as exemplified by the following: the F center or band is considered to originate from an excess electron near a negative ion vacancy; the F', from two excess electrons near a negative ion vacancy; the F_2, from two bound F-centers; the $F_2{}^+$, from one excess electron near two negative ion vacancies; the V_1, from an electron hole near a positive ion vacancy; the U, from added H ions in a negative ion vacancy; the M, from an F-center combined with two vacancies; the D, from an excess electron near a combined positive-negative ion vacancy.

COLOR, COMPLEMENTARY. Two colors are said to be complementary when they have complementary chromaticities (see **chromaticity, complementary**) and, on mixing in suitable proportions, yield a specified achromatic color.

COLOR COORDINATE TRANSFORMATION. Computation of the **tristimulus** values of colors in terms of one set of **primaries** from the tristimulus values of the same colors in another set of primaries. This computation may be performed electrically in a color-television system.

COLOR DECODER. A circuit in a color television receiver used to separate the three color signals.

COLOR DIFFERENCE SIGNAL. An electrical signal which, when added to the **monochrome signal,** produces a signal representative of one of the **tristimulus** values (with respect to a stated set of primaries) of the transmitted color.

COLOR DISCRIMINATION. Perception of differences between colors.

COLOR EDGING. Spurious color at the boundaries of differently-colored areas in the color-television picture. Color edging includes color fringing, misregistration, etc.

COLOR FILTER. A layer, film, or plate of a substance or material that absorbs or re-

flects certain frequencies and transmits other frequencies of light, thus changing the spectral distribution of the light energy.

COLOR MATCHING. Variation of the amount of the standard components in a **color mixture** until it does not differ visually from a given sample.

COLOR MIXTURE CURVE. A curve representing the amount of a standard component (usually specified in wavelength) required in a three-color mixture to match a sample color, for unit **flux** of spectral energy The variables plotted are usually the amount in **lumens** of the standard component and the indicated wavelength of the sample color matched

COLOR MIXTURE FUNCTION. A function having as variables the amounts or proportions of three standard color components, represented by the **color mixture curve.**

COLOR, NONSPECTRAL. (1) A color not present in the spectrum of white light (2) A color which can be represented by a point, on the **chromaticity diagram,** that lies on the straight line between the ends of the **spectrum locus,** or between that line and the **achromatic point.** (Definition by Committee on Colorimetry of the Optical Society of America)

COLOR PHASE (OF A GIVEN SUBCARRIER COMPONENT). The phase, with respect to the color-carrier reference, of that component of the **carrier-color signal** which transmits a particular color signal

COLOR PHASE ALTERNATION (CPA). The periodic changing of the color phase of one or more components of the **color subcarrier** between two sets of assigned values In the N.T.S.C system, the color phase is changed after every field It is recommended that the term "color phase alternation" be used in place of the terms oscillating color sequence and flip-flop, which have been used with this same meaning.

COLOR PICTURE SIGNAL. The electrical signal which represents color picture information, consisting of a monochrome component plus a subcarrier modulated with color information, excluding synchronizing signals.

COLOR PRIMARIES. See **primaries, color.**

COLOR SCREEN. A **color filter** used to exclude certain **frequencies** of light from a reaction system in order to control or modify a photo-process, physical or chemical.

COLOR SENSATION. A subjective experience constituting the primary conscious response to stimulation of the eye by radiant energy in the visible region

COLOR, SPECTRAL. A color represented by a point on the **chromaticity diagram** that lies on a straight line between the **spectrum locus** and the **achromatic point.**

COLOR SUBCARRIER. The **carrier** whose **modulation sidebands** are added to the **monochrome signal** to convey color information.

COLOR SYNC SIGNAL. See **color burst.**

COLOR THEORY. An explanation of the color of substances on the basis of their chemical structure and physical condition

COLOR TRANSMISSION. In television, the transmission of a signal wave for controlling both the **luminance** values and the **chromaticity** values in a picture

COLOR VISION, THEORY OF. Any psychophysiological theory which attempts to correlate color sensation with the spectral distribution of the radiant energy reaching the eye The early Young-Helmholtz theory of color vision has been followed by others, none of which are completely consistent with both psychophysical observations and anatomical evidence

COLORIMETER. (1) An instrument designed for direct measurement of colors (2) An instrument designed for the measurement of color, primarily by means of the visual equivalence of a sample to a synthesized stimulus (3) An instrument used for the empirical measurement of concentrations of solutions or the grading of products For this last use, the name "color comparator" is preferable

COLORIMETER, ABNEY. A **colorimeter** which combines light from two or more positions in a spectrum of white light for the purpose of producing colors of known characteristics

COLORIMETER, BROWN-MacADAM. A three-filter **colorimeter** embodying color

matches between nearly identical spectral distributions. The color to be matched is synthesized in an optical system using the same kind of lamp, filters and mirrors as those in the optical system used in matching, whereby when the colors are matched, the spectral distributions are identical.

COLORIMETER, DONALDSON. A trichromatic, additive **colorimeter** having filters, and mixing the components by diffusion in a coated, hollow sphere. A modified Donaldson colorimeter has six narrow-band filters, and is arranged so that an approximate spectral match is first obtained by using the filters successively in the eyepiece, followed by a final visual match without a filter.

COLORIMETER, EASTMAN. A subtractive colorimeter (see **colorimeter, empirical**) in which the sample is matched by light passing through three wedges, each belonging to a series that can be varied until the best match is obtained. The series are minus green, minus blue and minus red.

COLORIMETER, EMPIRICAL. A **colorimeter** using a series of selectively absorbing materials through which transmitted light is modified to match the sample. Also called "subtractive colorimeter."

COLORIMETER, GUILD. A trichromatic, additive **colorimeter** in which the amounts of the three components mixed are controlled by rotary shutter movement. A rotating periscopic prism presents the components rapidly.

COLORIMETER, GUILD VECTOR. A colorimeter designed for the direct determination of chromaticity by means of two successive matches, wherefrom the **chromaticity** of the sample is determined by the point of intersection of these two vectors in the **chromaticity diagram.**

COLORIMETER, IVES. A trichromatic **colorimeter** using filters, in which the amounts of the three component colors mixed is controlled by variable-width diaphragms.

COLORIMETER, NUTTING. A colorimeter for direct determination of **dominant wavelength** and **purity,** in which the sample color is matched by adding an adjustable standard white (achromatic) stimulus to the spectrum light from a prism.

COLORIMETER, PHOTOELECTRIC. A **colorimeter** in which the matching of a sample is effected by three filter-photocell combinations; although, of course, it is possible to use a single photocell successively to measure the light passing all three filters.

COLORIMETER, ROTATORY DISPERSION. A colorimeter in which a sample is matched by rotatory dispersion of polarized light by the adjustment of **Nicol prisms** (and intervening plates) and the instrument calibrated in terms of **chromaticity.**

COLORIMETRY. The science of color measurement.

COLORIMETRY, THREE-COLOR METHOD. A colorimetric method in which the sample is matched with a mixture of variable amounts of three components of light with different **chromaticites.**

COLORTRON. A three-gun, tricolor **kinescope.**

COLPITTS OSCILLATOR. See **oscillator, Colpitts.**

COLUMN. In positional notation a **position** corresponding to a given power of the **radix.** A digit located in any particular column is a coefficient of a corresponding power of the radix. Synonym: **place.**

COMA. One of the five geometrical aberrations of a lens with spherical surfaces. Skew rays from a point object do not meet at the same point on the image plane, but rather in a pear shaped spot (coma). The **Abbe sine condition** is a measure of coma. A lens system which is corrected for both spherical aberration and coma for a single object position is called aplanatic.

COMATIC CIRCLES. Rays from an off-axis point through any zone of a lens meet the **focal plane** in a comatic circle, the radius of which is in proportion to the radius of the **lens zone.**

COMB FILTER. See **filter, comb.**

COMBINATION. An assignment of a group of objects into two or more mutually exclusive sets. The **binomial coefficient** $\binom{n}{k}$ is the number of ways or **combinations** of selecting k objects from a set of n objects. If the k

objects are permuted among themselves, no new combinations are formed, but there are $k!$ new arrangements of each combination.

COMBINATION MICROPHONE. See **microphone, combination.**

COMBINATION PRINCIPLE. The principle, first recognized by Ritz, that the many frequencies exhibited by the spectrum of a substance can be regarded as differences between a comparatively few terms characteristic of the substance, taken two at a time in their various possible **combinations**. Ritz's statement was quite empirical, but we now understand that these terms correspond to the different possible energy states of the atom or molecule, and that the much more numerous spectral frequencies correspond to "jumps" or transitions from one state to another with consequent release or absorption of radiation quanta. For example, if an atom had twenty possible energy states or "levels," the number of possible transitions releasing energy would be theoretically $20 \times 19/2! = 190$.

It does not follow, however, that all of the corresponding frequencies are actually found in the spectrum; some are "forbidden," or of such rare occurrence as not to produce observable spectrum lines. When the principle is applied to certain **molecular spectra,** slight discrepancies are found which may be explained by assuming that some of the energy levels are not single but are close doubles. Such a discrepancy is known as a "combination defect."

COMBINATION SET. See **measurement.**

COMBINER CIRCUIT. See **circuit, combiner.**

COMMAND. In computer work, one of a set of several signals (or groups of signals) which occurs as the result of an instruction; the commands initiate the individual steps which form the process of executing the **instruction.**

COMMON-BASE CONNECTION. See **grounded-base connection.**

COMMON-COLLECTOR CONNECTION. See **grounded-collector connection.**

COMMON-EMITTER CONNECTION. See **grounded-emitter connection.**

COMMON ION EFFECT. The reversal of **ionization** which occurs when a compound is added to a solution of a second compound with which it has a common ion, the volume being kept constant. The degree of ionization of the second compound then is lowered, i.e., it retrogresses.

COMMUTATING CAPACITOR. See **capacitor, commutating.**

COMMUTATING REACTANCE. A **reactance** connected in the cathode lead of mercury-arc **rectifier** units to insure the current through the tube holding over when the voltage on the conducting **anode** drops until the next anode can pick up conduction. Without this, the arc would go out, and the tube would need restarting by some auxiliary means.

COMMUTATING REACTOR. See **commutating reactance.**

COMMUTATING RECTIFIER. Synonym for **free-wheeling rectifier.**

COMMUTATION. (1) For the use of this term in mathematics, see **commutator; commutative; commutation rules.** (2) A simple loop of wire rotating in a unidirectional magnetic field has induced in it a reversing or **alternating current.** When the conditions of usage make it desirable to have the current from the **generator** flow in one direction in the external circuit, commutation of some sort is required. The function of a commutator is to effect a reversal of the external connections to the winding of the generator at the proper time to produce a direct current in the connected circuit.

A single loop would generate a current which, when commutated, was pulsating in nature because of the varying rates at which the conductor, during rotation, cuts the lines of force of the **magnetic circuit.** The generator is composed of many such loops properly connected at their ends to the commutator. The commutator for a single loop would be simply a split ring with the two halves insulated not only from each other, but from the frame and shaft of the machine as well. In an actual practical generator having a multiplicity of windings, the commutator consists of a large number of segments of copper assembled around a hub which is attached to the shaft. The segments are thoroughly insulated from each other, usually with

mica, and to them the ends of the armature coils are soldered. **Brushes** bearing against the commutator conduct the current away from the generator.

COMMUTATION RULES. If any classical system is represented in terms of **generalized coordinates** and **momenta** q_l, p_k, the operators q_k, p_k in the corresponding quantized theory satisfy the rules

$$q_kp_l - p_lq_k = i\hbar\delta_{kl},$$

$$q_kq_l - q_lq_k = 0 = p_lp_k - p_kp_l.$$

Here δ_{kl} is the **Kronecker delta,** equal to unity if $k = l$ and to zero otherwise (See, however, **Jordan-Wigner commutation rules.**)

COMMUTATIVE. Describing the combination of two or more quantities when the result is independent of the order in which the operation is performed Thus, if $(a + b)$ $(b + a)$ or ab - ba, the processes are **commutative.** (See **operator, commutative; matrix, commutative.**)

COMMUTATOR. (1) If A and B are two non-**commutative** operators, their commutator is

$$[A,B] = AB - BA$$

According to quantum theory, if the commutator vanishes for two operators that represent dynamical variables, then the measurement of one of these variables does not interfere with that of the other (2) A mechanical device for periodically changing the connections to a rotating member, or for interchanging the connections of two leads to an electric circuit (See **commutation; electrical machinery; generator; dynamo.**)

COMMUTATOR-TYPE WATTHOURMETER. See **watthourmeter, commutator-type.**

COMMUNAL ENTROPY. The contribution to the **entropy** of a system arising from the disorder when the molecules are sufficiently free to change positions frequently.

COMPANDOR. (1) A transmission system in which the **signal-to-noise ratio** is improved by signal **compression** before transmission, and signal **expansion** after reception. (2) A speech-reproducing system consisting of a **compressor** of the volume range at the recording end and an **expander** of the volume range at the reproducing end.

COMPARATIVE LIFETIME. See **lifetime, comparative.**

COMPARATOR. (1) An instrument for the accurate measurement of moderately small lengths or distances. The feature common to various forms is a reading microscope or telescope arranged to travel along a scale, its axis remaining parallel to a fixed line. (2) A circuit which compares two signals and supplies an indication of agreement or disagreement This circuit is also known as an "add-or-subtract" circuit.

COMPARISON BRIDGE. An electric **bridge** used to determine the difference in impedance between two nearly equal and essentially similar circuit elements.

COMPASS. Any device which establishes direction on the earth's surface (Cf **compass, magnetic; gyrocompass.**)

COMPASS, FLUX-GATE. A compass operating on the principle of the magnetic modulator Three cores with appropriate excitation and load windings are arranged to be perfectly balanced in the absence of external fields The magnitude and phase of the unbalance voltage on the load windings is proportional to the magnitude and direction of the external (earth) magnetic field, respectively A **selsyn,** sensitive only to phase, is generally used as an indicator.

COMPASS, INDUCTION. A compass which determines the direction of the earth's magnetic field with the aid of a rotating coil. Maximum induced voltage in the coil indicates that the rotational axis of the coil is perpendicular to the magnetic field.

COMPASS, MAGNETIC. Any device which indicates the direction of the horizontal component of the earth's magnetic field. The term usually refers to a magnetized needle which is free to rotate in a horizontal plane.

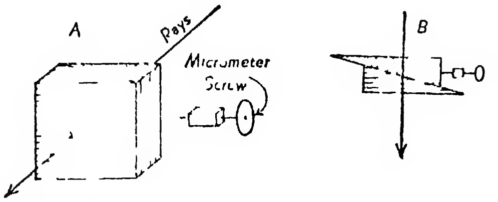
COMPASS, SATURABLE-REACTOR TYPE See **flux-gate magnetometer.**

COMPATIBILITY. The nature of a color television system which permits substantially-normal, monochrome reception of the transmission by typical, unaltered monochrome receivers designed for standard monochrome.

COMPENSATED WATTMETER. See **wattmeter, compensated.**

COMPENSATION THEOREM. If a network is modified by making a change, ΔZ, in the **impedance** of one of its branches, the current increment thereby produced at any point in the network is equal to the current that would be produced at that point by a compensating electromotive force acting in series with the modified branch, whose value is $-i\Delta Z$, where i is the original current which flowed in the modified branch.

COMPENSATOR. An arrangement for measuring the phase difference between the two components of elliptically **polarized light.** This is accomplished by introducing a known, opposite phase difference of equal magnitude, which reduces the existing phase difference to zero. The most familiar form, devised by



A Diagrammatic sketch of Babinet compensator, angle of wedges much exaggerated. Hatching and stippling indicate direction of crystal axes. B Shows wedges displaced.

Babinet, consists of two quartz wedges, with thin optic axes at right angles to each other. When passed through this apparatus and a **Nicol prism** set to extinguish light plane-polarized at 45° to either axis, any given elliptically polarized light produces a system of parallel dark bands. Plane-polarized light is first used (zero phase difference), then the elliptic light of unknown phase difference, and the relative displacement of the wedges necessary to restore the bands to their original position gives the phase difference required.

COMPLEMENT. In computer terminology, a number whose representation is derived from the finite positional **notation** of another by one of the following rules: (a) True complement—Subtract each digit from the **radix** less 1, then add 1 to the least significant digit, executing any carries required. (b) (Radix—1)'s complement—Subtract each digit from the radix less 1.

COMPLEMENTARITY PRINCIPLE. Physical phenomena may be described either in terms of particle motions characterized by a momentum p and an energy E, or in terms of waves characterized by a wavelength λ and a frequency ν. The two descriptions are connected by the equations:

$$p = h/\lambda \quad \text{and} \quad E = h\nu,$$

where h is the Planck constant. (See also **de Broglie wavelength, quantum, quantum mechanics.**)

COMPLEMENTARY FUNCTION. The solution to the **differential equation**

$$(D^2 + a_1 D + a_2)y = f(x)$$

may be written

$$y = e^{r_2 x}\int e^{(r_1 - r_2)x}\phi(x)dx + c_1 e^{r_1 x} + c_2 e^{r_2 x}$$

where r_1, r_2 are the roots of the **auxiliary equation** and

$$\phi(x) = \int_0^x e^{-r_1 x} f(x)dx.$$

The first term is a **particular integral** while the second and third terms on the right are the **complementary functions.** They form the complete solution of the corresponding **homogeneous differential equation**

$$(D^2 + a_1 D + a_2)y = 0.$$

The procedure and nomenclature are not limited to second-order equations but may be extended to those of any order.

COMPLEMENTARY WAVELENGTH. See **wavelength, complementary.**

COMPLETE RADIATOR. A temperature radiator of uniform temperature whose **radiant flux** in all parts of the spectrum is the maximum obtainable from any temperature radiator at the same temperature. Such a radiator is called a **black body** because it will absorb all the radiant energy that falls upon it. This condition can be realized in the laboratory only by having a hollow container with thick walls of high heat conductivity (to insure thermal equilibrium) and a very small hole from which radiation may escape. No known surface is truly black at all wavelengths.

COMPLETENESS. A set of functions $s_n(x)$ is complete if an arbitrary function, $f(x)$,

satisfying the same boundary conditions as the functions of the set, can be expanded as

$$f(x) = \sum_{n=1}^{\infty} a_n s_n(x)$$

the a_n being constant coefficients. This equation is to be read as: "the sum approximates $f(x)$ in the mean."

COMPLEX ION. See **ion, complex.**

COMPLEX ION, INSTABILITY CONSTANT OF. See **ion, instability constant of complex.**

COMPLEX NUMBER. See **complex variable.**

COMPLEX REFRACTIVE INDEX. The quantity n' defined by the equation:

$$n' = n(1 - ik)$$

where n' is the complex refractive index, n is the customary **refractive index** and k is the **absorption index.** This form of the refractive index is especially useful in the study of metallic reflection. (See **Fresnel equations for metallic reflection.**)

COMPLEX TONE. See **tone, complex.**

COMPLEX VARIABLE. A complex number has the form $(a + ib)$, where a,b are real numbers and $i = \sqrt{-1}$. It thus consists of a real part a and a pure imaginary part ib. In the study of complex numbers they are generally regarded as an order pair of real numbers (a,b) subject to the following laws: (1) equality, $(a,b) = (c,d)$ if and only if $a = c$, $b = d$, (2) addition, $(a,b) + (c,d) = (a + c, b + d)$; multiplication, $(a,b) \times (c,d) = (ac - bd, ad + bc)$. (Cf. **amplitude; absolute value; phase.**)

A complex number may be represented graphically on an **Argand diagram.**

If x and y are two real variables, then $z = (x + iy)$ is a complex variable. It becomes a complex number if x and y are constants.

COMPLIANCE, ACOUSTIC. The reciprocal of acoustic stiffness (see **stiffness, acoustic**). Its dimensions are $[M^{-1}L^4T^{-2}]$. This definition applies to single frequency quantities in the steady state, and to systems whose properties are independent of the magnitude of these quantities.

COMPLIANCE CONSTANTS. See **elastic constants.**

COMPONENT. (1) In its general usage, one of the ingredients of a mixture, or one of the distinct molecular or atomic species composing a mixture. In physical chemistry, one among the smallest number of chemical substances which need to be specified in order to reproduce a given chemical **system.** (2) The projection of a **vector** on a particular coordinate **axis** or along some specified direction. (3) For component of a tensor, see **tensor, contravariant; tensor, covariant.**

COMPOSITE-COIL WATTMETER. See **wattmeter, composite-coil.**

COMPOSITE COLOR SIGNAL. The color picture, including **blanking signals** and all **synchronizing signals.**

COMPOSITE PICTURE SIGNAL. In television, the signal which results from combining a **blanked picture signal** with the **sync signal.**

COMPOSITE WAVE FILTER. See **filter, composite wave.**

COMPOUND. A homogeneous, pure substance composed of two or more essentially different chemical elements, which are present in definite proportions; compounds usually possess properties differing from those of the constituent elements.

COMPOUND, COMPLEX. A **compound** which is made up structurally of two or more compounds or **ions.**

COMPOUND, COORDINATION. One of a number of types of complex compounds, usually derived by addition from simpler inorganic substances. Coordination compounds are essentially compounds to which atoms or groups have been added beyond the number possible on the basis of electrovalent **linkages** or the usual covalent linkages, to which each of the two atoms linked donates one electron to form the duplet. The coordinated groups are linked to the atoms of the compound usually by semipolar covalences, in which both the electrons in the bond are furnished by the linked atom of the coordinated group. The ammines and complex cyanides are representative coordination compounds.

COMPOUND, COVALENT. A compound formed by the sharing of electrons between atoms; as distinguished from electrovalent compounds, in which there occurs a transfer of electrons.

COMPOUND HORN. See **horn, compound.**

COMPOUND, INTERMETALLIC. A **compound** consisting of metallic atoms only, which are joined by metallic bonds. Such compounds may be made **semiconducting** if the two metals between them contribute just sufficient electrons to fill the valence band, e.g., InAs.

COMPOUND, INTERSTITIAL. A **compound** of a metal or metals and certain metalloid elements, in which the metalloid atoms occupy the interstices between the atoms of the metal lattice. Compounds of this type are, for example, TaC, TiC, ZrC, NbC, and similar compounds of carbon, nitrogen, boron, and hydrogen with metals.

COMPOUND, IONIC. One of a class of **compounds** which ionize readily in aqueous solution, and which are formed when atoms combine to produce molecules having stable configurations by the transfer of one or more electrons within the molecule. This type of combination is illustrated by the combination of sodium atoms and chlorine atoms to form sodium chloride. The sodium atom loses the single electron in its outer shell, and thus is left with the stable configuration of eight electrons; the chlorine atom acquires an electron to increase the number of electrons in its outer shell from seven to eight; as a result of the loss and gain of the electrons, the atoms have acquired positive and negative charges, respectively, which constitute an electrovalent bond, that is disrupted in water and other polar solvents to yield sodium and chloride ions.

COMPOUND, MOLECULAR. A **compound** formed by the union of two or more already saturated molecules apparently in defiance of the laws of **valence.** The class includes double salts, salts with water of crystallization, and metal ammonium derivatives. These salts are usually formed by **van der Waal's** attraction between the constituent molecules. They do not differ in any characteristic manner from compounds formed in strict accordance with the concept of valence. They are also called addition compounds.

COMPOUND, NONPOLAR. A **compound** in which the centers of positive and negative charge almost coincide so that no permanent **dipole moments** are produced. The term nonpolar also applies to compounds in which the effect of oppositely directed dipole moments cancel. Nonpolar compounds may contain polar bonds, if their effect is canceled by opposing bonds, as may occur in a perfectly symmetrical molecule. Nonpolar compounds do not ionize or conduct electricity. Most organic compounds are to be classed as nonpolar compounds.

COMPOUND NUCLEUS. See **nucleus, compound.**

COMPOUND, POLAR. In general, a **compound** that exhibits **polarity,** or local differences in electrical properties, and has a **dipole moment** associated with one more of its interatomic **valence bonds.** Polar compounds have relatively high **dielectric constants,** associate readily in most cases, and include the substances that exhibit **tautomerism.** In the most general use of the term, polar compounds include all **electrolytes,** most inorganic substances, and many organic ones. Specifically, the term polar compound is frequently applied to the extreme type of polarity which arises in the presence of an electrovalent bond or, in wave-mechanical terms, to cases in which one ionic term dominates in the orbital function of the molecule. Such compounds are exemplified by the inorganic acids, bases, and salts which possess, to a greater or lesser degree, the power to conduct electricity, associate, form double molecules and complex ions, etc.

COMPOUND, SATURATED. A **compound** in which the **valence** of all the atoms is completely satisfied without linking any two atoms by more than one valence bond.

COMPOUND, TRACER. A **compound** which by its ease of detection enables a reaction or process to be studied conveniently. Wide use has been made of **isotopes,** including radioactive isotopes of common elements, which are added in small quantities, in the form of the proper compound, to follow the course of an atom or a compound through a compli-

cated series of reactions; or conversely to determine the properties of a tracer—that is available only in quantities too small to handle alone—by adding it to a system containing chemically related elements, and then following its course throughout a given series of reactions. Considerable use of tracer compounds is made in the study of physiological reactions.

COMPRESSIBILITY. Relative change of volume per unit of pressure, $-dV/VdP$. In other words, the compressibility is the reciprocal of the **bulk modulus.**

COMPRESSIBILITY FACTOR. Defined as pV/RT, where p is the pressure, V the volume, R the gas constant, and T the absolute temperature. It has the value 1 for an **ideal gas,** but may be greater or less than 1 for real gases.

COMPRESSION. (1) In general usage, compression is descriptive of the decrease of volume of a compressible substance (solid, liquid or gaseous) due to the application of pressure. The common example of compression is found in cylinders filled with gas being compressed by the motion of a piston moving in the cylinder. The pressure increase required for any given reduction of volume of a gas depends upon the particular condition surrounding the act of compression; for example, if the cylinder is thoroughly insulated against heat transmission, the compression will be of a type known as **adiabatic,** and the temperature of the gas will rise during compression because the mechanical work expended on the piston in obtaining the compression is converted into heat energy in the gas. On the other hand, if the cylinder is a good conductor of heat, and passes heat to the atmosphere as rapidly as it is received by the gas, the temperature at the end of compression may be the same as that at the beginning. In this isothermal compression the pressure at the end of compression is less than that of an equivalent adiabatic compression. In general, actual compressions are neither strictly adiabatic nor isothermal. (2) In structural engineering compression is used to denote the type of stress which causes the fibers of a member to shorten. (3) In electronics, the ratio of the small-signal power gain g_0 of a device to the power gain g_1 at some higher power level. Expressed in decibels:

$$\text{Compression} = 10 \log_{10} \frac{g_0}{g_1}.$$

(See **compressor.**) (4) In television, the reduction in **gain** at one level of a picture signal with respect to the gain at another level of the same signal. (See also **black compression** and **white compression.**) The gain referred to in the definition is for a signal amplitude small in comparison with the total peak-to-peak, **picture signal** involved. A quantitative evaluation of this effect can be obtained by a measurement of **differential gain.**

COMPRESSION, MODULUS OF. See **bulk modulus.**

COMPRESSION RATIO. See **ratio of expansion.**

COMPRESSIONAL WAVE. See **wave, compressional.**

COMPRESSOR, VOLUME. In amplitude **modulation** systems of **radio communication** the amount of intelligence volume which can be modulated upon the **carrier** is limited to an amount which will give 100% modulation. Since the percentage of modulation depends directly upon the volume of the sound, it follows that, in order not to exceed the allowable modulation on very loud sounds, the percentage on most sounds will be rather low. Since the maximum use is made of the power and a higher signal to noise ratio is obtained for high degrees of modulation, it is very desirable to keep the level of modulation as high as possible. To do this the volume range of the original sound is compressed into a much smaller range. Thus, while a symphony orchestra may have a volume range of 100–110 **db,** the range is compressed to about 40 db for broadcast purposes. In recordings the maximum volume which may be recorded is limited by the thickness of the groove walls so the volume range is reduced here also. An **expander** may be used in the reproducing system of the radio circuit or the phonograph to restore the original range. (See **amplifier, volume-limiting.**)

COMPTON ABSORPTION. The absorption of an x-ray or γ-ray **photon** in the **Compton effect.** Part of the energy of the photon is absorbed, and part appears as a photon of lower energy.

COMPTON EFFECT. Elastic scattering (see **scattering, elastic**) of photons by electrons. Because the total energy and total momentum are conserved in the collisions, the wavelength of the scattered radiation undergoes a change that depends in amount on the **scattering angle.** If the scattering electron is assumed to be at rest initially, the Compton shift is given by the following equation:

$$\lambda' - \lambda = \lambda_0(1 - \cos\theta) = (h/m_e c)(1 - \cos\theta),$$

where λ' is the wavelength associated with the scattered photons, λ is the wavelength associated with the incident photons, λ_0 is the **Compton wavelength** of the electron and θ is the angle between the paths of incident and scattered photons.

COMPTON METER. An **ionization chamber** especially useful for cosmic ray measurements. It is of the compensating type, using a balance chamber with a uranium source which is adjusted until it balances out the normal cosmic radiation. Variations in this radiation are shown on the collecting system, which is connected to an **electrometer.**

COMPTON RECOIL ELECTRON. An electron set in motion by interaction with a photon in the **Compton effect.**

COMPTON RECOIL PARTICLE. A particle which gains its momentum by a scattering process similar to the **Compton effect.**

COMPTON RULE. An empirical relationship between thermal properties of elements, of the form:

$$\frac{(\text{At. Wt.})(L_f)}{T_f} = 2,$$

in which At. Wt. is the atomic weight, L_f is the **heat of fusion**, and T_f is the fusing point (in degrees absolute).

COMPTON SCATTERING. See **Compton effect.**

COMPTON SCATTERING, DOUBLE. See **double Compton scattering.**

COMPTON SHIFT. Discussed under **Compton effect.**

COMPTON-SIMON EXPERIMENT. Fundamental experiment demonstrating the quantum nature of x-rays by scattering them by electrons in a Wilson cloud chamber and observing that the energy and momentum balance corresponds to an energy $h\nu$, momentum $h\nu/c$ per quantum, where h is the **Planck constant,** and ν is the **frequency.**

COMPTON WAVELENGTH. A wavelength characteristic of a particle of rest mass m_0, and evaluated by the relationship:

$$\lambda_0 = h/m_0 c$$

where λ_0 is the Compton wavelength, h is the Planck constant, m_0 is rest mass of the particle and c is the velocity of light. (See also **Compton effect.**)

COMPUTER. A device which can accept information and supply information, and in which the supplied output information is derived from the accepted input information by means of a process of logic, i.e., any systematic process of derivation which is demonstrably free from self-contradiction.

CONCAVE GRATING. An optical **grating** ruled on a concave, spherical reflecting surface, which not only acts as a grating but serves also to focus the image of the slit without the use of a lens.

CONCENTRATION. Either the process of increasing the quantity of a substance or form of energy or other entity that exists in a volume of space, as in increasing by evaporation the amount of solute contained in unit volume in a solution, or as in gathering heat, light, electricity, or other energy or form of energy; or the quantity itself of matter or other entity that exists in a unit volume, as the strength of a solution in mass of solute per unit mass of solution, or in the number of moles, hydrogen ions, etc., contained per unit volume or per unit mass.

CONCENTRATION, ABSOLUTE. The quantity of a substance, or form of energy or other entity that exists in a unit volume, expressed in mass per unit volume (ergs per cubic centimeter), or number of particles (as of atoms, hydrogen-ions, etc.) per unit volume.

CONCENTRATION CELL. See **cell, concentration.**

CONCENTRATION CELL, ELECTRODE. See **cell, electrode concentration.**

CONCENTRATION, CRITICAL. When two immiscible liquids are heated in contact with each other their mutual solubility is usually increased until, at the **critical solution point,** they become **consolute.** The composition of the two solutions immediately before they become consolute is termed the critical concentration.

CONCENTRATION, IONIC. The number of **gram-ions** (calculated from the atomic weight of the substance or substances composing the ion) contained in unit volume of solution.

CONCENTRATION POLARIZATION. See **polarization, concentration.**

CONCENTRIC LINE. Another name for **coaxial line.**

CONCENTRIC LINE OSCILLATOR. See **oscillator, coaxial line.**

CONCURRENT FORCES. See **statics,** also **forces, concurrent.**

CONDENSATION. (1) Change from gaseous (or vapor) state to liquid state. (2) In general, increase in density. (3) The local increase in density in a sound wave, as contrasted with **rarefaction:** quantitatively,

$$s = \frac{\rho - \rho_0}{\rho_0},$$

where s is the condensation, ρ the local instantaneous density, ρ_0 the constant mean density at an point. (4) Accumulation of electric charge, as of electrons in a condenser (see **capacitor, electric**). (5) Convergence of light, or formation of a beam of parallel light rays. (6) In chemistry, various combination reactions of molecules to form larger molecules.

CONDENSATION, COEFFICIENT OF. It can be shown from kinetic theory that for a solid or liquid in equilibrium with its vapor at pressure and temperature T, the mass of vapor molecules striking (and therefore also leaving) unit area per second is

$$\mu = p\sqrt{M/2\pi RT}$$

where M is the molecular weight of the vapor, and R the gas constant. If it can be assumed that every molecule striking the surface is condensed, this expression will also give the rate of loss of weight of the solid or liquid at temperature T in a vacuum. If the assumption is not justified, the rate of loss of weight can be written

$$\mu = \alpha p\sqrt{M/2\pi RT}$$

the constant α being known as the coefficient of condensation. Experiments appear to show that this may be considerably less than unity in some cases.

CONDENSATION IN THE ATMOSPHERE. **Clouds** and precipitation are visible evidence that water vapor in the atmosphere condenses into liquid and solid water. Moisture in cloud form may be re-evaporated into the air, but rain, snow, and allied forms of precipitation actively lessen the total water content. This moisture loss by precipitation, considering the world at large, is replaced by equivalent evaporation of moisture into the atmosphere.

Nuclei upon which condensation can take place are absolutely necessary. Non-ionized and pollution-free air will become up to 400% supersaturated before condensation occurs. On the other hand, clouds sometimes form before air becomes 100% saturated. Nuclei upon which condensation begins at the approach toward saturation are highly hygroscopic and encourage condensation. Minute salt crystals, primarily sodium, magnesium and calcium chlorides, carbonates, and sulfates, smoke particles, and ions serve as condensation nuclei. Lowering of the temperature of air below its **dew point,** or adding water vapor beyond the holding capacity of the air, is a second requirement for the formation of clouds.

CONDENSED - MERCURY TEMPERATURE (OF A MERCURY-VAPOR TUBE). By definition, the temperature measured on the outside of the tube envelope in the region where the mercury is condensing in a glass tube, or at a designated point on a metal tube.

CONDENSED SYSTEM. A substance or mixture of substances in the liquid or solid state. The term has also been applied to the condensation into a state of zero momentum of the particles in a ideal gas obeying **Bose-Einstein statistics.**

CONDENSER, ELECTRIC. See **capacitor, electric.**

CONDENSER FORMULAS. See **capacitor formulas.**

CONDENSER LOUDSPEAKER. See **loudspeaker, electrostatic.**

CONDENSER MICROPHONE. See **microphone, electrostatic.**

CONDENSER MODULATOR. Essentially a capacitor microphone (see **microphone, capacitor**) which is driven by some form of electromechanical or electroacoustic **transducer.** The resulting change in capacitance is used as a variable impedance element in the modulated stage.

CONDENSER PLATE. A **capacitor** electrode.

CONDENSER R-METER (CONDENSER IONIZATION CHAMBER). Ionization instrument for measuring x- or γ-rays, consisting of an **electrometer** and a detachable **ionization chamber,** embodying a condenser of suitable capacitance. This can be attached to the electrometer and the entire system charged. It is then detached from the electrometer, exposed to the radiation and returned to the electrometer for reading the decrease in charge. The instrument can be calibrated to read directly in **roentgens** at the position of the center of the chamber over a considerable range of photon energies, provided the ionization chamber is suitably constructed.

CONDUCTANCE. The real part of **admittance.** In a non-reactive element, the reciprocal of the resistance.

CONDUCTANCE, EQUIVALENT. The electrical conductance of a solution which contains one gram-equivalent weight of solute at a specified concentration, measured when placed between two electrodes which are 1 cm apart.

CONDUCTANCE FOR RECTIFICATION. The quotient of the electrode alternating current of low frequency by the in-phase component of the electrode alternating voltage of low frequency, a high-frequency sinusoidal voltage being applied to the same or another electrode and all other electrode voltages being maintained constant.

CONDUCTANCE, INPUT OR CATHODE-GRID. See **transit time; transit angle.**

CONDUCTANCE, IONIC. The amount contributed by each characteristic ion to the total equivalent conductance in infinite dilution. Thus, in the mathematical expression of the law of independent migration of ions:

$$\Lambda_0 = \lambda_+ + \lambda_-$$

in which λ_+ and λ_- are the ionic conductances of cation and anion, respectively, and Λ is the total equivalent conductance (see **conductance, equivalent**) of the electrolyte.

CONDUCTANCE MOLAR. The electrical conductance of a solution which contains one **mole** of **solute** at a specified concentration, measured when placed between electrodes which are one centimeter apart.

CONDUCTANCE OF ELECTROLYTE. The **conductance** (ohm^{-1}) and **conductivity** (ohm^{-1} cm^{-1}) are defined for **electrolytes** as for any **conductor.** In addition for electrolytes, much use is made of the "equivalent conductance", this is the product of conductivity and the volume (in cm^3) containing 1 gram-equivalent of electrolyte.

CONDUCTANCE OF ELECTROLYTE, MEASUREMENT OF. To avoid errors introduced by **polarization** at the electrode, the **conductance** of **electrolytes** is measured with low-voltage alternating current in a **bridge.**

CONDUCTANCE RATIO. The ratio of the equivalent conductance of a given ionic (electrolytic) solution to its equivalent conductance at infinite dilution.

CONDUCTANCE, SPECIFIC. See **conductivity, electrical.**

CONDUCTION. The transmission of energy (heat, sound, electricity) by means of a medium without movement of the medium itself, as distinguished from convection, in which such movement occurs, or from radiation in which the energy quanta pass through the medium and so the transmission does not occur by means of the medium. (See **conduction, electric; thermal conduction.**)

CONDUCTION BAND. According to the **band theory of solids,** a partially-filled energy band in which the electrons can move freely, allowing the material to carry an electric current. Such a band could then be called a conduction band, but the term is usually re-

stricted to the case of **semiconductors** and **insulators,** where the conduction band is normally empty, and is separated by an energy-gap from the full bands below it.

CONDUCTION CURRENT. See **current, electric.**

CONDUCTION, ELECTRIC. The conduction of electricity in material substances is of two general kinds. (1) A migration of ionized (and hence electrified) atoms or molecules, as discussed in this book under **ionized gases** and **electrolytes.** (2) A process in which the atoms are in the main stationary, as in metals.

The electric conductivity of solids has an almost unbelievable range. For silver and sulfur (the best and the poorest among elements), the ratio is something like 1000 billions of billions to 1. Their resistivity is, of course, in the inverse ratio. (See **resistance.**) Metals, as a class, aside from being almost immeasurably better conductors, differ in several respects in their conduction from non-metals. For example, the conductivity of pure metals consistently decreases with rising temperature, while the non-metallic solids, including carbon, generally have maximum conductivity at one or more temperatures. Selenium has most extraordinary properties (see **photoconductivity**). Some metals exhibit **superconductivity** near the **absolute zero** of temperature. The alloying of metals, and even the admixture of small quantities of impurities, often profoundly affects the conductivity. Thus "constantan," an alloy of copper and nickel, shows almost no change of conductivity with temperature. The **Wiedemann-Franz law** expresses the remarkable relation which exists between the electric and the thermal conductivities of metals. The various **thermoelectric phenomena, thermionic phenomena,** the **Hall effect,** etc., must also be taken into account by any theory of metallic conduction. (See also **semiconductor.**)

CONDUCTION, IONIC, IN SOLIDS. Since the ions of an **ionic crystal** may diffuse through the lattice, a small electrical conductivity is possible even though the material should otherwise be insulating. The process is very sensitive to temperature (see **mobility of ions in solids**), and at low temperatures is also strongly dependent on the structure and purity of the material.

CONDUCTION, METALLIC. The **conduction** of electricity through solids wholly (or almost so) by the migration of **electrons.**

CONDUCTION, THERMAL. The processes of heat transport through a substance, excluding heat transfer due to mass flow in the substance. The heat flowing per unit time through a sample with cross-section A and length l under a temperature difference ΔT is given as $Q = KA\Delta T/l$, where K is a material constant called the thermal conductivity of the substance. More generally, $Q/A = -KdT/dl$, where the negative sign indicates that the heat flow is in the opposite direction to the temperature gradient, dT/dl.

CONDUCTIVITY, ACOUSTIC. The ratio of the volume current through an orifice to the difference in **velocity potential** between the two sides of the orifice. Its dimensions are those of cm.

CONDUCTIVITY, ELECTRICAL. The conductance of a centimeter cube, measured in mhos/cm It is given by the ratio of **current density J** to applied **electric field E:**

$$\mathbf{J} = \sigma \mathbf{E}.$$

According to the **free electron theory of metals,** the conductivity of electrons in a perfect lattice should be infinite. This is also true, in the **band theory of solids,** for an unfilled electronic band. However, the lattice always contains imperfections and impurities, and is always in a state of agitation by thermal vibrations, which scatter the conduction electrons. In a general way, one may write

$$\sigma = \frac{Ne^2}{\sqrt{2mE_F}} \cdot \Lambda(E_F)$$

where σ is the electrical conductivity, e and m the charge and mass of an electron, N the number of free electrons, E_F the **Fermi energy,** and $\Lambda(E_F)$ the **mean free path** of an electron at the Fermi energy. The density of thermal vibrations, at high temperatures, is proportional to the absolute temperature, so that the mean free path, and hence the conductivity varies as $1/T$. At low temperatures the theory is complicated, but the conductivity then varies as $1/T^5$, until it is limited by the **residual resistance** due to imperfections and impurities, for which the mean free path is nearly independent of temperature.

CONDUCTIVITY APPARATUS. An apparatus for determining the conductivity of a liquid or solution. It consists of a **conductivity cell**, with all the accessory equipment for measuring resistance, and for measuring and controlling temperature.

CONDUCTIVITY CELL. A **cell** for determining the conductivity of a solution (or fused solid), consisting of a chamber containing two electrodes.

CONDUCTIVITY MODULATION (OF A SEMICONDUCTOR). The variation of the conductivity of a **semiconductor** by variation of the charge **carrier** density.

CONDUCTIVITY, N-TYPE. The conductivity associated with **conduction electrons** in a **semiconductor.**

CONDUCTIVITY, P-TYPE. **Conductivity** in which the current appears to be carried by positive charges, as by **holes** in an impurity semiconductor. (See **semiconductor, impurity.**)

CONDUCTOR. A material which, when placed between terminals having a difference of **electrical potential**, will readily permit the passage of an electric current is an electrical conductor. Different materials have different degrees of conductivity, and their effectiveness in this respect is computed as the **conductivity.** (See also **semiconductor.**)

CONDUCTOR, FORCE ON. See **force on conductor.**

CONE. (1) a solid formed by a closed **conical surface** and a plane, called the base of the cone, cutting the surface in a closed curve Depending on the surfaces from which they are formed, cones are described as square, rectangular, elliptical, circular, etc., these terms designating the section obtained by a plane through the cone, parallel to its base.

The names cone and conical surface are frequently used interchangeably but it is proper to distinguish between them for one is a solid and the other is a surface. (2) A receptor cell in the retina of the eye. Cones respond only to fairly high level of illumination, but distinguish between colors. (See **rod.**)

CONE OF NULLS. A conical surface formed by directions of negligible radiation.

CONE OF SILENCE. See **radio range.**

CONFIGURATION, ATOMIC. The arrangement in space of the atoms of a molecule.

CONFIGURATION, ELECTRONIC. An assignment of electrons to various states or **orbitals** in a molecule or crystal.

CONFIGURATION, INTERACTION. Calculations of bond energy of molecules depend on assuming that the electrons are to be found in certain **orbitals**, for which approximate forms must be assumed. To improve the calculation it is necessary to consider the admixture into the wave function of functions corresponding to other electronic configurations, supposed to represent excited states of the molecule.

CONFIGURATIONAL ELASTICITY OF A LIQUID. The compressibility of a liquid depends in part on resistance to compression owing to the thermal agitation of the molecules and in part on disturbance of the **short range order.** The contribution from the latter is the configurational elasticity.

CONFLUENCE. The merging of **singularities** of a differential equation upon variation of the parameters of the equation. The confluent hypergeometric equation is

$$xy'' + (c - x)y' - ay = 0$$

and is so-called because it is obtained from the **hypergeometric equation** by confluence of the singularities at $x = 1$ and $x = \infty$. Special cases of it are the differential equations of **Hermite, Weber,** and **Whittaker.**

CONFORMABLE. See **matrix, conformable.**

CONFORMAL. A transformation of a complex function by the **transform** F, $w = F(z)$ is conformal wherever F is **analytic.** An infinitesimal figure in the z-plane is mapped into a similar infinitesimal figure in the w-plane. An alternate statement is that two intersecting curves in the z-plane are mapped into two curves in the w-plane with the same angle of intersection.

CONFORMAL WIRE GRATING. A **wave filter** made of wires bent to conform to the lines of electric field that are characteristic of the wave that is to be reflected.

CONGRUENT MELTING POINT. A point on a **phase diagram** where a solid compound

of two **components** melts to a liquid of the same composition.

CONIC. A **conic section.**

CONIC, CENTRAL. A **conic section** which is symmetric about a finite point on the plane of the curve. If this point, called the center, is at the origin of the coordinate system the equation contains no terms of the first degree in x and y. The central conics are the **hyperbola,** the **ellipse,** and a special case of the latter, the **circle.** The **parabola** is a non-central conic since its center is at infinity.

CONIC, CONFOCAL. A system of two **conics** having the same foci. Its equation in standard form is

$$\frac{x^2}{A - q} + \frac{y^2}{B - q} = 1$$

where $A > B$ and q is a variable **parameter.** If q is less than B or negative, both denominators are positive and the resulting curves are **ellipses;** if $A > q > B$, the curves are **hyperbolas;** if $q < A$, the curves are imaginary.

The two families of conics have the same foci, for the distance from the center to a focus is $\sqrt{(A - q) - (B - q)} = \sqrt{A - B}$, in both cases. Through every point in the plane two curves intersect and the curves are mutually perpendicular at that point. Thus if the point of intersection is described by the two real roots of the quadratic equation in q, these numbers locate the point in a two-dimensional **curvilinear coordinate system,** often called **elliptical coordinates.**

A degenerate case is a system of two families of **parabolas,** opening in opposite directions. Since the curves are mutually perpendicular, they also may be used as a curvilinear coordinate system in two dimensions. The name **parabolic coordinates** is used for this system as well as for the three-dimensional case obtained by revolving the parabolas about their common axis.

CONIC, DEGENERATE. One of the limiting forms of a **conic section:** one or two straight lines or a point. It is represented by a **quadratic equation in two variables** if the **discriminant** of the equation vanishes.

CONIC SECTION. A curve described in Cartesian coordinates, usually but not necessarily rectangular coordinates, by an algebraic equation of the second degree in two variables

$$Ax^2 + Bxy + Cy^2 + Dx + Ey + F = 0.$$

The shape of the curve is determined by the values assigned to the constants $A, B, \cdots, F$ and relations assigned to them. The possibilities are: **ellipse, hyperbola, parabola, degenerate conic.** (See **quadratic equation in two variables.**)

A conic section may also be defined as the **locus** of a point which moves so that its distance from a fixed point, the **focus,** is in a constant ratio, the **eccentricity,** to its distance from a fixed straight line, the **directrix.** Each curve is obtained by a cutting plane through a right circular **conical surface.**

CONICAL COORDINATE. A degenerate system of **curvilinear coordinates** obtained from an **ellipsoidal** system. The surfaces are: spheres with center at the origin of a rectangular system and radii u (u = const.); two sets of **cones** with apexes at the origin, one along the Z-axis and the other along the X-axis (v, w = const.). Conical coordinates are related to rectangular coordinates by the equations

$$x^2 = \frac{u^2v^2w^2}{b^2c^2}$$

$$y^2 = \frac{u^2(v^2 - b^2)(w^2 - b^2)}{b^2(b^2 - c^2)}$$

$$z^2 = \frac{u^2(v^2 - c^2)(w^2 - c^2)}{c^2(c^2 - b^2)}$$

where $c^2 > v^2 > b^2 > w^2$.

CONICAL HORN. See **horn, conical.**

CONICAL REFRACTION. A narrow ray entering properly into a biaxial crystal may be propagated as a cone within the crystal (internal conical refraction). A convergent beam of light focused on a pinhole in a screen covering one face of a biaxial crystal may leave a pinhole in a screen on the opposite face as a cone (external conical refraction).

CONICAL SCANNING. See **scanning, conical.**

CONICAL SURFACE. A surface generated by a moving line intersecting a fixed curve and passing through a fixed point. The line

is the **generatrix**; the curve is the **directrix**; the point is the **vertex**. Its general equation, if the vertex is taken at the origin of a Cartesian coordinate system, is

$$Ax^2 + By^2 + Cz^2 + 2Fyz + 2Gxz + 2Hxy = 0.$$

Depending on the curve chosen as the directrix, the surface is square, rectangular, elliptical, etc. If the directrix is an ellipse in the plane $z = c$ with semi-axes a and b and the vertex is taken at $x = y = z = 0$, the resulting equation is

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} - \frac{z^2}{c^2} = 0.$$

The axis of the conical surface is then the Z-axis and the coordinate origin is a center of symmetry. Two surfaces are thus produced, one for positive values of z and its mirror image for negative z. These are the two **nappes** of the conical surface.

If the directrix is a circle, $a = b$ and the surface is called right circular.

CONICOID. A **quadric surface.**

CONJUGATE. For a **complex number**, $u + iv$, the conjugate or conjugate complex is $u - iv$. It is obtained by changing the sign of the imaginary part. This process is often designated by the asterisk, thus A^* is conjugate to A. The product of an expression and its conjugate is always real.

The term conjugate is also used in **group theory** but with a different meaning. (See **transform.**)

CONJUGATE FOCI. The interdependent distances between object and lens and lens and image are known as the conjugate distances. As the distance from the object to the lens increases, that from the lens to the image decreases and vice versa. The formula expressing the geometrical relation between these distances is:

$$1/f = 1/v + 1/u$$

where f is the **focal length** of the lens, v, the lens-to-image distance, and u, the object-to-lens distance. The ratio of the conjugate distances determines the size of the image. Thus:

$$R = v/u$$

where R is the relative size of the image to the object. If $u = v$, $1/f = 2/u$ and $u = 2f$. Then the total $u + v = 4f$, which is the minimum possible distance between real image and real object for a lens with positive focal length.

The definitions of v and u given here are applicable only to a thin lens. The equations apply to any lens system, however, if v and u are measured respectively from and to the appropriate **principal planes** of the lens or the lens system.

CONJUGATE IMPEDANCES. See **impedances, conjugate.**

CONJUGATE POINT. (1) A **singular point** on a curve which is the real intersection of imaginary **branches** of the curve. The condition which must be met is

$$\left(\frac{\partial^2 f}{\partial x\, \partial y}\right)^2 - \frac{\partial^2 f}{\partial x^2}\frac{\partial^2 f}{\partial y^2} < 0.$$

Also called an isolated point.

(2) Because of the one-to-one relation between the object-space and the image-space of an **optical system**, for each point or ray in one space there is a conjugate point or ray in the other space.

CONJUGATE SOLUTIONS. A system in **equilibrium** consisting of two liquid phases and two components. If the components of such a two-component system are designated as A and B, then one phase is a solution of component A in component B, and the other phase is a solution of component B in component A. Such liquids are spoken of as "partially miscible."

CONNECTED NETWORK. See **network, connected.**

CONNECTIVITY. A **domain** bounded by a smooth curve is said to be simply connected. Any closed curve in the domain can be shrunk to a point by continuous deformation without crossing the boundary. When more than one continuous arc is required to form the boundary, the domain is multiply connected and the minimum number of arcs required to form the boundary is the connectivity.

CONPERNIK. A trade name for a 50% nickel-iron, isotropic magnetic alloy.

CONSERVATION OF ENERGY, LAW OF. The total quantity of energy in a closed system is constant. The law of the conservation

of energy is often called the first law of thermodynamics. or simply the first law.

In view of the recognition that energy and mass are mutually convertible, which results from special relativity theory, this law must be recognized as a special case of the conservation of mass energy. It is applicable only when no conversions of mass to energy or energy to mass take place, or when the energy of the system is understood to include all the mass of the system converted to energy units by multiplication by the square of the speed of light.

CONSERVATION OF MASS, LAW OF. (Law of the conservation of matter.) This law has been put in the form that matter can neither be created nor destroyed. More accurately, the total mass of any system remains constant under all transformations. For the interpretation of this law in the light of relativity theory, see **conservation of energy, law of; mass-energy relation.**

CONSERVATIVE SYSTEM (CONSERVATIVE FORCES). A system of particles in which the forces acting on any particle of the system are forces which can be derived from a potential energy function. There must exist a potential energy function $V(x, y, z)$ such that the components of the resultant of these forces are given by

$$F_x = -\frac{\partial V}{\partial x}$$

$$F_y = -\frac{\partial V}{\partial y}$$

$$F_z = -\frac{\partial V}{\partial z}$$

or the resultant force vector $\mathbf{F} = -\nabla V$. The forces which satisfy this condition are called conservative forces. (Cf. **potential energy.**) In a conservative system, the work required to move a particle from one point to another depends only on the positions of the two points, not on the path followed between them.

CONSISTENCY. (1) The degree of **viscosity** or **fluidity** of a liquid, a the degree of **firmness** or **plasticity** of a solid. (2) The relative amount of solid material in a mixture.

CONSISTOMETER. A testing apparatus for measuring the **hardness** (consistency) of materials. Its essential element is a pointed plunger which is dropped from a fixed height on the material being tested; the depth of penetration is a measure of the relative hardness of the material.

CONSOLUTE. Completely miscible. Term applied to liquids when they are miscible in all proportions, i.e., mutually completely soluble, under some given conditions. Not usually applied to gases which are all miscible.

CONSOLUTE TEMPERATURE. The upper consolute temperature for two partially-miscible liquids is the critical temperature above which the two liquids are miscible in all proportions. In some systems where the mutual solubility decreases with increasing temperature over a certain temperature range, the lower consolute temperature corresponds to the critical temperature below which the two liquids are miscible in all proportions. Some systems such as methylethyl ketone and water have both upper and lower consolute temperatures.

CONSONANCE. When two or more musical tones played simultaneously produce a pleasing effect on the listener the tones are said to be in consonance The general condition for consonance is that the frequencies of all the sounds have the ratios of small whole numbers.

CONSONANT ARTICULATION. See **articulation, consonant.**

CONSTANT. An absolute constant is a single number which always has the same value. An arbitrary constant or **parameter** is one which has only one particular value in a given case, but may have another value in another case Arbitrary constants are often represented by letters, as a, b, c, etc., from the first part of the alphabet.

CONSTANT AMPLITUDE RECORDING. See **recording, constant amplitude.**

CONSTANT-ANGLE FRINGES. See **Haidinger fringes.**

CONSTANT BOILING MIXTURES. See **boiling mixtures, constant.**

CONSTANT BOILING POINT. See **boiling point, constant.**

CONSTANT-CURRENT CHARACTERISTIC. The relation, usually represented by a graph, between the voltages of two electrodes, with the current to one of them, as well as all other voltages, maintained constant.

CONSTANT-CURRENT (HEISING) MODULATION. See **modulation, constant-current (Heising).**

CONSTANT-DEVIATION FRINGES. See **Haidinger fringes.**

CONSTANT-DEVIATION PRISM. See **prism, constant-deviation.**

CONSTANT(S), ELASTIC. See **elastic constants.**

CONSTANT HEAT SUMMATION, LAW OF. (Law of Hess.) The energy change involved in a chemical reaction or series of reactions in going from the initial condition of the system to the final condition is always the same and is independent of the intermediate course the reaction takes.

CONSTANT(S), LINE. See **line, transmission.**

CONSTANT - LUMINANCE TRANSMISSION. A method of color transmission in which the **carrier color signal** controls the **chromaticity** of the produced image without affecting the **luminance,** the luminance being controlled by the **monochrome signal.**

CONSTANT OF INTEGRATION. An arbitrary **constant** or **parameter** which must be added to any function resulting from an integration in order to obtain the general solution or **primitive.** Thus the general solution of an nth order **differential equation** will contain n constants of integration.

CONSTANT-RESISTANCE STRUCTURE. A structure whose iterative impedance (see **impedance, iterative**), in at least one direction, is a resistance and is independent of the frequency.

CONSTANT VELOCITY RECORDING. See **recording, constant velocity.**

CONSTANT VOLUME METHOD FOR VAPOR PRESSURE. A known weight of the substance is vaporized in a constant, known volume at a known temperature, and the increase in pressure measured. The apparatus consists of a glass bulb surrounded by a constant-temperature bath and connected to a limb of a mercury manometer, the level in this limb being kept at the same height before and after vaporization. Knowing the weight of the vapor and its volume, the density can be calculated at the temperature of the experiment, and at a pressure equal to the partial pressure of the vapor, which is equal to the increase in pressure observed.

CONSTITUTION. (1) The arrangement of the atoms in the molecule. (2) A diagram designed to show the relative positions of atoms and groups in two dimensions. When the arrangement is considered in three dimensions, so as to show spacial relationships, it is called a configuration.

CONSTRAINED MOTION. See **kinetics.**

CONSTRAINT. Any particle or collection of particles is said to be subject to constraint if the number of **degrees of freedom** is less than $3N$, where N is the number of particles. (Cf. the **D'Alembert principle** and the **Gauss principle of least constraint.**) Specifically that property which distinguishes a mechanism from other mechanical linkages. A mechanism has constrained motion in that a motion of one part is followed by a predetermined motion of the remainder of the mechanism. To determine whether a mechanical linkage is a mechanism or not, Klein advocates applying the criterion of constraint, which he writes as follows:

$$J = \frac{3N - 4 + \gamma - P}{2}$$

in which J is the number of joints in the mechanism, N is the number of links in the mechanism, γ is the number of independent prismatic chains, that is, those whose joints are of the sliding type, P − the number of point or line type of contact joints in the mechanism. When this equation yields an identity, the mechanism is said to be constrained for all dimensions.

CONTACT ANGLE. The angle formed by a liquid on the surface of a solid at the gas-solid-liquid interface, measured as the dihedral angle in the liquid. Its value depends on the relative surface energies of the three interfaces, vapor-solid, vapor-liquid and solid-liquid.

CONTACT, HIGH RECOMBINATION RATE. A **semiconductor**-semiconductor or metal-semiconductor contact at which thermal equilibrium **carrier** densities are maintained substantially independent of current density.

CONTACT, MAJORITY CARRIER (TO A SEMICONDUCTOR). An electrical contact across which the ratio of **majority carrier** current to applied voltage is substantially independent of the polarity of the voltage, while the ratio of **minority carrier** current to applied voltage is not independent of the polarity of the voltage.

CONTACT MICROPHONE. See **microphone, contact.**

CONTACT NOISE. The fluctuating electrical resistance observed at the junction of two metals, or of a metal and a **semiconductor.**

CONTACT POTENTIAL. (1) The potential difference observed between the surfaces of two metals in contact. It is due to the differences in **work function;** the electrons in each metal tend to reach the same **Fermi level,** and potential builds up until this is established. A distinction must be made between the contact potentials in air and the so-called "intrinsic" contact potentials in a vacuum with all adsorbed gases removed. According to Millikan, the intrinsic potential difference between two metals A and B is expressed by $V_{AB} = h(\nu_A - \nu_B)/e$, in which h is the **Planck constant,** ν_A and ν_B are the critical frequencies of photoelectric emission for the two metals (see **photoelectric phenomena**), and e is the electronic charge In any case, if the electronic **work functions** of the metals are p_A and p_B, the contact potential difference is $V_{AB} = (p_A - p_B)/e$. The work functions, and hence V_{AB}, are in general dependent upon the medium surrounding the metals. Accurate measurements of these potentials are, unfortunately, very difficult.

(2) Colloquialism for the negative potential required to **bias** the **grid** of a **vacuum tube** to the point of zero grid current (usually 0.1 to 1.0 volt).

CONTACT RECTIFIER See **rectifier, contact.**

CONTACT TRANSFORMATION. See **canonical transformation.**

CONTINENTAL CLIMATE. The type of climate characteristic of the interior of a continent.

CONTINUA. See **spectrum, continuous.**

CONTINUITY EQUATION (PRINCIPLE OF CONTINUITY). The application of the principle of conservation of mass to fluid motion. It expresses the local rate of increase of density as the negative of the **divergence** of the mass flow. In the Eulerian formulation,

$$\frac{\partial \rho}{\partial t} + \operatorname{div} \rho \mathbf{v} = 0$$

where ρ is fluid density and $\mathbf{v}$ is the flow velocity. Both ρ and $\mathbf{v}$ are functions of space and time. For an incompressible fluid, the divergence of the velocity is zero.

The continuity equation applies to any flow of a conserved quantity, such as electric charge, energy or momentum.

CONTINUITY OF STATE. **Transition** between two states, as between the gaseous and liquid states, in either direction, without discontinuity, or abrupt change in physical properties. Although this transition is not realizable in practice by mere pressure-volume change, it can be accomplished by some processes, as by a sequence of temperature changes in one direction at constant volume, followed by temperature changes in the other direction at constant pressure, or vice versa.

CONTINUOUS CREATION HYPOTHESIS. Hypothesis that the universe is being created continuously by the formation, without apparent mechanism, of one nucleon per 10^9 year-liter, a rate too small to be directly detected, but sufficient to keep the average density constant despite the expansion of the universe. Galaxies which have receded to a distance of more than 2×10^9 years are supposed to disappear from view, and the whole universe is in dynamic equilibrium, recently created matter forming into galaxies to replace those which are lost. Thus the universe is in a steady state, although the matter which composes it is being continually changed. This creation of matter throughout all space, without local energy conservation, is so great a mystery that the theory has not been generally accepted.

CONTINUOUS-DUTY RATING. See **rating, continuous-duty.**

CONTINUOUS SPECTRUM. See **spectrum, continuous.**

CONTINUOUS WAVES OR CW. See **waves, continuous or CW.**

CONTINUOUS X-RAYS. See **x-rays, continuous.**

CONTOUR. (1) A smooth curve made of arcs bound together continuously, each arc having a continuous tangent. A closed contour may be decomposed into a series of closed smooth curves having no multiple points. If the closed contour is traversed in a counter-clockwise direction with respect to some point in the domain, the sense of the contour is positive. Integration along a closed contour, C is indicated by the symbols

$$\int_C \text{ or } \oint$$

and the result is a contour integral. (See **calculus of residues.**) (2) A curve in a two-dimensional space, along which some function of position has a specified constant value. Thus a line on a map connecting points having the same height is a height contour or a potential energy contour.

CONTRACTED RIEMANN-CHRISTOFEL TENSOR. The tensor $G_{\mu\nu} = B^{\epsilon}{}_{\mu\nu\epsilon}$ where $B^{\epsilon}{}_{\mu\nu\sigma}$ is the **Riemann-Christoffel tensor.** Summation on the repeated index ϵ is implied.

CONTRACTION. A process used to reduce the rank of a tensor. (See **tensor, contraction.**)

CONTRACTION, COEFFICIENT OF. See **coefficient of contraction.**

CONTRACTION OF MEASURING-RODS. If a rod of **proper length** l moves longitudinally with velocity v with respect to an observer, the length of the rod appears to this observer to be

$$l\left(1 - \frac{v^2}{c^2}\right)^{1/2}.$$

(c is the velocity of light.) (See **relativity, special theory of.**)

CONTRAST. (1) In photography, the slope of the curve plotted between **density** and the log of **exposure** (see **H and D curve**). (2) In television, the ratio between the maximum and minimum brightness values in a picture. (3) In psychophysics, the change in the response to a stimulus as a result of the proximity in space or time of other stimuli. In general, the response to a stimulus of given physical intensity is reduced if neighboring stimuli have greater intensities, and vice versa.

CONTRAST CONTROL. In television, a **potentiometer** that permits variations of the intensity of the various elements of an image. May be used to accentuate the highlights and shadows in an image.

CONTRAST SENSITIVITY. If the difference in brightness ΔB of a small spot against a larger background of brightness B is just discernible, the contrast sensitivity is defined as $\Delta B/B$.

CONTRAVARIANT (TENSOR). A particular kind of tensor. (See **tensor, contravariant.**)

CONTRAVARIANT VECTOR. Any set ϕ^μ of four functions of the coordinates x^μ which under a general coordinate transformation $x^\mu \rightarrow x'^\mu$ becomes

$$\phi'^\mu = \sum_\nu \frac{\partial x'^\mu}{\partial x^\nu} \phi^\nu.$$

The notion is of particular use in the general relativity theory. (See **relativity, general theory of.**)

CONTROL. (1) A system or device which exerts a restraining, governing or directing influence. (2) An experiment or test done to confirm or to rule out error in experimental observations.

CONTROL ANGLE. Synonym for **saturation angle.**

CONTROL CHARACTERISTIC. (1) Of a **magnetic amplifier,** a curve of the output quantity versus control quantity under specified conditions, both expressed in suitable units. (2) Of a gas tube, a curve of the **critical grid voltage** versus **anode voltage.**

CONTROL CIRCUIT. (1) Of a magnetic amplifier, the control windings and the voltage sources and impedances which are con-

nected to them, and which together determine the current in the **control windings.** (2) The circuits of a **digital computer** which effect the carrying out of instructions in proper sequence, the interpretation of each instruction, and the application of the proper commands to the arithmetic element and other circuits in accordance with this interpretation.

CONTROL CIRCUIT A-C SUPPLY VOLTAGE (RESET CIRCUIT A-C SUPPLY VOLTAGE). An a-c voltage, appearing in the control circuit of a **magnetic amplifier,** the purpose of which is, in conjunction with the action of the signal, to accomplish resetting of the saturable reactor core flux during resetting intervals of the cycle.

CONTROL CIRCUIT IMPEDANCE. Control circuit impedance of a **magnetic amplifier** consists of two parts: (a) The external control circuit impedance includes the external control circuit reactance and, usually, the entire control circuit resistance. (b) The internal control winding impedance consists of the control winding reactance and control winding resistance.

CONTROL CIRCUIT REACTANCE. Control circuit reactance of a **magnetic amplifier** consists of two parts: (a) The reactance of the control winding of one saturable reactor when unsaturated; this reactance is also called internal control winding reactance. The control winding reactance is related to the gate reactance by the square of the turns ratio of the saturable reactor. (b) The reactance of the control circuit external to the control winding is called the external control circuit reactance.

CONTROL CIRCUIT, RESET. That circuit of a **magnetic amplifier** through which controlled resetting of the saturable reactor core flux is accomplished. This circuit is comprised of the saturable reactor control winding(s), the signal(s) and any other parameters which may be used in conjunction with these to accomplish the desired controlling action.

CONTROL CIRCUIT RESISTANCE, EQUIVALENT. Of a **magnetic amplifier,** the parallel equivalent of all the control circuit resistances referred to the same turns basis, usually that of an output winding.

CONTROL CIRCUIT RESISTANCE, REFLECTED. The resistance of a **control circuit** when referred to some arbitrary turns basis, usually that of an output winding.

CONTROL, CONVERGENCE. See **convergence control.**

CONTROL CURRENT. In **amplifiers,** the current whose magnitude determines the magnitude of output.

CONTROL ELECTRODE. See **electrode, control.**

CONTROL GRID. See **grid, control.**

CONTROL HYSTERESIS. A control **characteristic** which is double-valued. This may be encountered in **amplifiers** with excessive amounts of positive **feedback,** or in some forms of **magnetic amplifiers** with inductive load. Sometimes called "snap action."

CONTROL, LOCAL. A system or method of radio-transmitter control whereby the control functions are performed directly at the transmitter.

CONTROL, MASTER GAIN (VOLUME). A control provided in broadcast or recording studios to permit adjustment of the over-all output level of the studio without affecting the balance achieved by the **mixer controls.** It is also useful for **fading** purposes.

CONTROL POINT. The value of the **controlled variable** which, at any instant, an **automatic controller** operates to maintain.

CONTROL RATIO (OF A GAS TUBE). The ratio of the change in anode voltage to the corresponding change in **critical grid voltage,** with all other operating conditions maintained constant.

CONTROL TRACK. A supplementary sound track, usually placed on the same film with the sound track carrying the program material. Its purpose is to control, in some respect, the reproduction of the sound track. Ordinarily, it contains one or more tones, each of which may be modulated either as to amplitude or frequency.

CONTROL TURNS. In **magnetic amplifiers,** the turns wound on the core(s) which carry the **control current.**

CONTROL, VERTICAL HOLD. In television, the control which varies the free-running period of the **vertical-deflection oscillator.**

CONTROL WINDINGS. Of a saturable reactor, those windings by means of which control magnetomotive forces are applied to the core.

CONTROLLED (VARIABLE OR FLOATING) CARRIER. See **carrier, controlled (variable or floating).**

CONTROLLED - CARRIER MODULATION. See **modulation, controlled-carrier.**

CONTROLLED VARIABLE. That quantity or condition which is measured and controlled by an **automatic controller.**

CONVECTION. (1) The transference of heat by the bodily movement of heated particles of matter, as the heating of buildings by steam, hot air, or hot water (2) The transfer of mass by streaming motion

CONVECTION CURRENTS. (1) See **current, electric.** (2) In atmospheric physics, air currents that travel vertically Convection can be either mechanical or thermal Orographical and frontal lifting are mechanical convections of whole layers of air whirlwinds, dust devils, **cumulus clouds** and **thunderstorms** are results of small-scale convection.

CONVECTION, FORCED. The transport of heat through the motion of a locally heated fluid if this motion is produced by other agencies than the gravitational effect on the variation in density with temperature.

CONVECTION, NATURAL. The transport of heat through the motion of a fluid which is locally heated, if this motion is solely due to changes in the density of the fluid

CONVECTIONAL PRECIPITATION. Precipitation from clouds caused by thermal instability, i.e., clouds of the cumulus or cumulonimbus type.

CONVERGENCE. (1) A series converges if, and only if, the sum of the first n terms approaches a limit as n is increased indefinitely, i.e., if

$$|S_n - L| < \epsilon$$

for all ϵ, however small, and for all n greater than some fixed N. Here L is a finite number, the **limit,** and S_n is the sum of the first n terms. (See also **Cauchy convergence test.**) (2) In meteorology, an inflowing of air into a region from more than one direction in such manner that more air flows in than flows out. So long as this process continues, it will tend to produce an increasing pressure and temperature, with their consequent effects. (3) In a three-gun, color **kinescope,** the focusing of the three electron beams on a common point, usually the **aperture mask.**

CONVERGENCE CONTROL. The control in a color television receiver which adjusts the potential on the convergence electrode of the **kinescope** for convergence of the beams

CONVERGENCE MAGNETS. Three permanent magnets placed around the **purity coil** of a three-gun, color **kinescope** used to adjust the beams (in conjunction with the **convergence control**) for proper convergence of the electron beams

CONVERSION. In general, a change, often with the force of a directed or induced change One specific use is a change in numerical value of a quantity resulting from the use of a different unit in the same or a different system of measurement (See **conversion factor.**)

CONVERSION COEFFICIENT. See **conversion fraction.**

CONVERSION ELECTRON. An electron emitted in the process of de-excitation of the nucleus by direct coupling between the excited nucleus and an electron in the K, L, or M shells or possible other shells, constituting the process of internal conversion Such an electron has a kinetic energy which is the difference between the transition energy and the binding energy of that electron. Internal conversion is followed by emission of characteristic **x-rays** or of **Auger electrons** as a consequence of the necessary rearrangement of the atomic electrons.

CONVERSION EFFICIENCY. In vacuum tube **amplifier** and **oscillator** circuits, the **a-c** (usually radio frequency) power output divided by the d-c power input to the plate circuit. It is also called the plate efficiency.

It varies quite widely with different classes of amplifiers, running as high as about 80% in some class C amplifiers, from 30 to 70% (depending upon conditions) in class B and being of the order of 20% in the usual class A amplifier.

CONVERSION FACTOR. (1) The ratio of two measures of the same physical quantity, in different units. Thus, one statute mile is exactly equivalent to 5280 feet, and we may express this fact by saying that the ratio 5280 ft/1 mi = 1. Quantities expressed in one unit may then be transformed to another unit by multiplication or division by the conversion factor. Thus

$$15 \text{ mi} = 15 \text{ mi} \times (5280 \text{ ft}/1 \text{ mi}) = 79{,}200 \text{ ft}$$

or

$$39{,}600 \text{ ft} = 39{,}600 \text{ ft} \times (1 \text{ mi}/5280 \text{ ft}) = 7.500 \text{ mi}.$$

(2) The term is often used to refer to the numerical value of the conversion factor as defined above, i.e., 5280 is the conversion factor to change a distance expressed in miles to the same distance expressed in feet.

CONVERSION FRACTION. The ratio of the number of internal **conversion electrons** to the number of quanta emitted plus the number of conversion electrons emitted in a given mode of de-excitation of a nucleus. Partial conversion fractions refer to conversion fractions for various electron shells, e.g., K-conversion fractions, L-conversion fractions, etc. Sometimes called conversion coefficient.

CONVERSION GAIN. In a nuclear **reactor,** the **conversion ratio** minus one.

CONVERSION GAIN RATIO. In communications, the ratio of the available signal power at the output to the available signal power at the input of a **frequency converter** or **mixer.**

CONVERSION RATIO. In a nuclear **reactor,** the number of fissionable atoms produced per fissionable atom destroyed.

CONVERSION TRANSCONDUCTANCE (OF A HETERODYNE CONVERSION TRANSDUCER). The quotient of the magnitude of the desired output-frequency component of current by the magnitude of the input-frequency (signal) component of voltage when the impedance of the output external termination is negligible for all the frequencies which may effect the result. Unless otherwise stated, the term refers to the cases in which the input-frequency voltage is of infinitesimal magnitude. All direct electrode voltages and the magnitude of the local-oscillator voltage must remain constant.

CONVERSION TRANSDUCER (FREQUENCY CONVERSION TRANSDUCER). See **transducer, conversion.**

CONVERTER. A machine or device for changing alternating current to direct current, or the converse. If a conversion is made from d-c to a-c, the machine is called an inverted converter. The most common type of rotating converter at present is the rotary converter, which is essentially an **alternator** and d-c **generator** combined in one machine having a single **armature** and a single-field circuit. This is not to be confused with a motor-generator set which, although it may be classed as a converter, is basically two machines having separate armatures, and shafts connected by a **coupling.** The rotary converter receives a-c at one set of terminals, and delivers d-c at another. The energy delivered is less than that received by the amount of the converter losses, consisting of friction, resistance heat, and core losses. The converter is frequently called a synchronous converter or rotary converter.

CONVERTER, MAGNETIC. See **modulator, magnetic.**

CONVERTER TUBE. See **tube, converter.**

CONVERTIBLE LENS. See **lens, convertible.**

CONVOLUTION. If f and g are both functions of the **complex variable** z, the **convolution or faltung** of f and g, often indicated by the symbol $(f * g)$ is the integral

$$f * g = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(\xi)g(z - \xi)d\xi.$$

Let $\mathfrak{F}$ be the **Fourier transform** of the integral, then

$$\mathfrak{F}(f * g) = \mathfrak{F}(g * f) = \mathfrak{F}(f)\mathfrak{F}(g).$$

This theorem also applies directly to the **Laplace transform** and with minor modifications to the **Mellin transform.**

CONWELL-WEISSKOPF FORMULA. The **mobility** μ of electrons in a **semiconductor** in the presence of **donor** or **acceptor impurities** is given by

$$\mu = [2^{7/2}\epsilon^2(kT)^{3/2}\log(1 + x^2)]/Ne^{\pi^{3/2}e^3m^{1/2}}$$

where

$$x = 6\epsilon dkT/e^2$$

and ϵ is the dielectric constant of the medium, N is the concentration of ionized donors (or acceptors), $2d$ is the average distance between ionized donors, e and m the electronic charge and mass, etc.

"COOKE TRIPLET." See **camera lenses.**

"COOKIE CUTTER." See **magnetrons, methods of tuning.**

COOLIDGE TUBE. A hot-cathode, self-rectifying type of **x-ray tube.**

COOLING BY ADIABATIC DEMAGNETIZATION. See **adiabatic demagnetization, cooling by.**

COOLING CURVE. A graphical representation of the temperature of a substance plotted against time, such as is obtained for a molten alloy cooling through its solidification temperature or range of temperatures.

COOPERATIVE PHENOMENON. Any process for whose occurrence the simultaneous interaction between several molecules or systems is required. Most typical are **order-disorder transformations**, and **ferromagnetism**, where every atom in a crystal may participate.

COORDINATE. One of the numbers used to locate the position of a point relative to a **coordinate system.** In three-dimensional systems, if the point is on a coordinate surface one coordinate is zero; if it is on a coordinate axis, two coordinates are zero.

COORDINATE AXIS. A direction along which only one of the coordinates of a point changes as the point moves in this direction. In three dimensions, an **axis** is the intersection of two coordinate surfaces. The axes may be mutually perpendicular or inclined at any arbitrary angle.

COORDINATE, CURVILINEAR. Three parameters which determine the position of a point in a triply orthogonal **coordinate system**, or only two, if the point lies on a surface.

COORDINATE POTENTIOMETER. See **potentiometer, coordinate.**

COORDINATE SURFACE. The surface in a **coordinate system** obtained by setting one coordinate equal to a constant.

COORDINATE SYSTEM. Surfaces used for locating the position of a point; three if in space but only two if in a plane. When the surfaces are mutually perpendicular, the system is **curvilinear** or **orthogonal;** if the surfaces are planes, the system is **rectangular;** if the surfaces do not intersect at right angles, the system is said to be **affine** or **non-orthogonal.**

COORDINATE VALENCE. See **bond, coordinate.**

COORDINATES AND MOMENTA, GENERALIZED. Generalized coordinates are coordinates chosen to describe the motion of a mechanical system, without having their exact nature immediately specified. The generalized coordinates associated with a system having n **degrees of freedom** are denoted by $q_1, q_2, \cdots q_n$. In the final analysis of a particular problem, the generalized coordinates must be translated into a known set, such as, for example, rectangular, cylindrical, or spherical.

The generalized momenta $p_1, p_2, \cdots p_n$ are defined by the equation:

$$p_i = \frac{\partial L}{\partial \dot{q}_i}$$

where L is the **Lagrangian function** for the system. The generalized **momentum** p_i is said to be conjugate to the generalized coordinate q_i. The **Lagrange equations** and the Hamilton **canonical equations** are expressible in terms of generalized coordinates and momenta.

COORDINATION NUMBER. The number of **nearest neighbors** of a given atom in a **crystal structure.** In **covalent crystals,** only those neighbors to which the atom is directly bonded are counted, and this number is usually four or less. In **metals** the coordination number may be as high as twelve, as in the close-packed structures.

COORDINATION POLYHEDRA. The arrangement of oxygen ions about the **cation** to which they are closely bonded, in an **ionic crystal,** as, for example, the group (SiO_4), which forms a tetrahedron. Such polyhedra pack as units in the crystal structure.

COPPER. Metallic element. Symbol Cu. Atomic number 29.

COPPER-OXIDE MODULATOR. See **modulator, copper-oxide.**

COPPER-OXIDE PHOTOVOLTAIC CELL. See **photovoltaic cell, copper-oxide.**

COPPER-OXIDE RECTIFIER. See **rectifier, copper-oxide.**

COPPER-SULFIDE RECTIFIER. See **rectifier, copper-sulfide.**

CORE. (1) A magnetic core is an important element in many applications in electrical design. Electromagnetic equipment, as exemplified by the transformer, the motor and the generator, have electrical circuits, usually of copper conductors, and magnetic circuits. The magnetic circuit follows a path largely contained in a core composed of iron or iron alloys. The purpose of the core is to offer a low-reluctance path for the magnetic flux established by the electrical circuits, and its success in this respect is measured by its permeability. (2) In a nuclear **reactor**, the region containing the fissionable material; in a **heterogeneous reactor,** the region containing fuel-bearing cells. (3) In an atom, the aggregate consisting of the nucleus plus all electrons in closed shells. The valence electrons may often be considered to be moving in a field due to the spherically symmetrical charge $+ze$ of the core, z being the number of valence electrons.

CORE LOSSES. The power losses in a magnetic **core** caused by **hysteresis** and **eddy currents.** The hysteresis loss is caused by the currents which are induced in the core material by the changing flux through it. This is, of course, much more pronounced in a-c than in d-c machines, because of the much greater rate of change of the flux in the former. In order to reduce this loss the cores of all a-c machinery and much d-c machinery are laminated or composed of thin sheets. The hysteresis loss is due to the interaction between the fields of the molecules of the core and the external magnetic field. While the two types of losses do not follow the same laws the total loss varies approximately as the square of the frequency if other factors are held constant.

CORING. A variation in composition within the dendrites or grains of a cast solid-solution phase caused by failure to achieve equilibrium during solidification. The alloy which initially solidifies, contains a greater proportion of the component which raises the freezing temperature of the liquid, and the interior (core) of the **dendrite** is thereby enriched in this component.

CORIOLIS EFFECTS (ACCELERATION OR FORCE). (1) Any object moving above the earth with constant space velocity is deflected relative to the surface of the rotating earth. This deflection was first discussed by the French scientist Coriolis about the middle of the last century, and is now usually described in terms of the Coriolis acceleration or the Coriolis force. The deflection is found to be to the right in the northern hemisphere and to the left in the southern. If $\dot{\mathbf{r}}_{ma}$ is the vector velocity of a particle with respect to the earth ($\mathbf{r}$ is measured from the center of the earth), then the Coriolis acceleration is given by $-2\boldsymbol{\omega} \times \dot{\mathbf{r}}_{ma}$ where $\boldsymbol{\omega}$ is the angular velocity of rotation of the earth.

The Coriolis effects must be considered in a great variety of phenomena in which motion over the surface of the earth is involved. Among these may be listed: a. Rivers in the northern hemisphere should scour their right banks more severely than the left, and the effect should be more evident for rivers in high latitudes. Studies of the banks of the Mississippi and Yukon rivers indicate the predicted results. b. The motions of air over the earth are governed, to an appreciable extent, by the Coriolis force. c. A term, due to the Coriolis force, must be included in the equations for exterior ballistics. While the effect is negligible in small-arms fire, nevertheless, it is very important in the fire-control material for long-range guns. d. Any level bubble, which is being carried on a ship or plane, will be deflected from its normal position. The deflection will be perpendicular to the direction of motion of the ship or plane The correction for this effect may amount to several miles in the determination of a position of the ship or plane by methods of celestial naviga-

tion if the bubble octant is used in the necessary observations.

(2) A generalized discussion of Coriolis effects, not limited to the earth as a frame of reference, is given in polar coordinates as follows: A particle which is subject to no forces in a polar coordinate system r, θ experiences a radial acceleration $r(d\theta/dt)^2$ and a tangential acceleration $-2(dr/dt)(d\theta/dt)$. These accelerations result from the fact that every point fixed in a coordinate system rotating with an angular velocity $d\theta/dt$ (with the exception of the origin) is accelerated with respect to an inertial frame. The radial acceleration is known as the **centrifugal acceleration;** the tangential acceleration is called the Coriolis acceleration. If Newton's second law of motion is applied to the particle without correction for the motion of the coordinate system, a **centrifugal force** $mr(d\theta/dt)^2$ and a Coriolis force $-2m(dr/dt)(d\theta/dt)$, where m is the mass of the particle, must be postulated to account for the behavior of the particle.

CORNEA. The outermost part of the eye just in front of the aqueous humor.

CORNER REFLECTOR. (1) A reflector (see **reflector (2)**) consisting of two or three mutually-intersecting, conducting surfaces. Corner reflectors may be dehedral or trihedral. Trihedral reflectors may be used as radar targets. (2) A reflector which consists of two plane-conducting surfaces set at an angle of 45° to 90° with the driven element on a line bisecting the angle. The reflecting surfaces are not necessarily solid, but can be made from wires spaced about 0.1 wavelength apart. In a given amount of space, the corner reflector gives better directivity than the parabolic reflector.

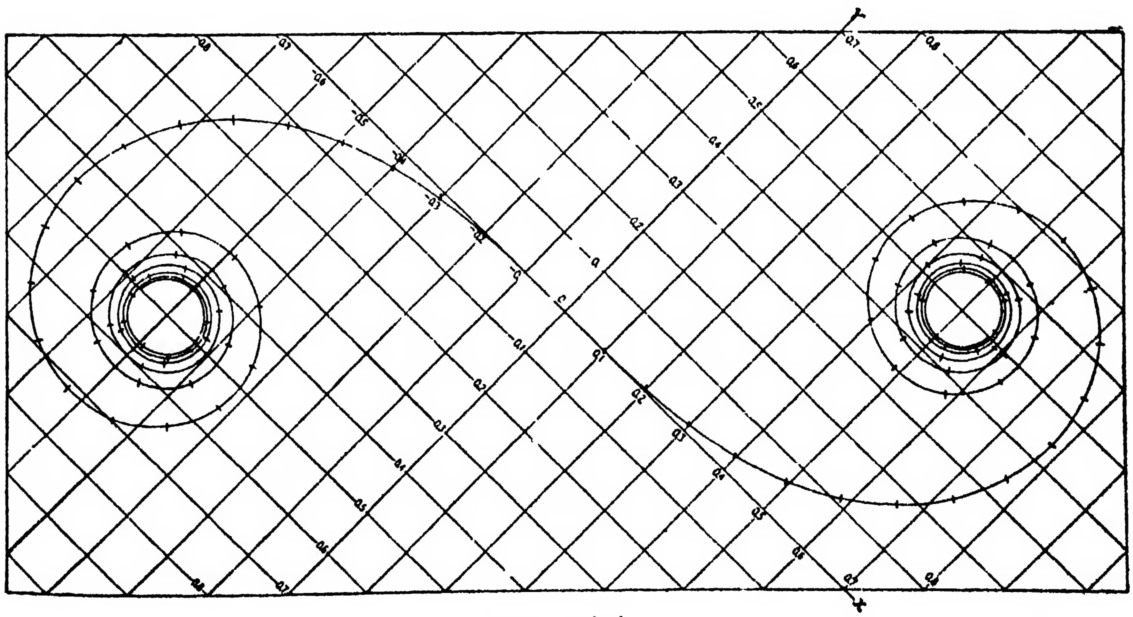
CORNU DOUBLE PRISM. In order to make use of the ultraviolet-transmitting properties of quartz without introducing its double refraction, Cornu made a compound prism by cementing together two 30-degree prisms, one of right-handed and one of left-handed quartz.

CORNU-JELLET PRISM. A prism made by splitting a Nicol (see **prism, Nicol**) in a plane parallel to the direction of vibration of the transmitted light and removing a wedge-shaped section. When the two pieces are joined together again, the planes of vibration of the light transmitted by the two halves make a small angle with each other.

CORNU POLARISCOPE. A combination of a **Wollaston prism,** and a **Nicol prism** used as an analyzer.

CORNU SPIRAL. A plot of

$$x = \int_0^v \cos \frac{\pi v^2}{2}\, dv$$



Cornu spiral

against

$$y = \int_0^v \sin \frac{\pi v^2}{2}\, dv.$$

This gives a double spiral curve. Distances on this curve are used in computing intensities in the **diffraction pattern** resulting from **Fresnel diffraction.**

CORONA. (1) **Diffraction** of light from either the sun or moon through **cloud** water-droplets produces a corona or series of colored rings which appear about the celestial body but actually are at the cloud height. Corona differs from **halo** in that the latter is due to refraction by ice crystals. Reddish colors always occupy the outer part of the ring (2) Also **corona discharge.** (3) The luminous region which may be seen about the sun during a total solar eclipse.

CORONA DISCHARGE. The discharge brought about as a result of the ionization of gas surrounding a conductor, which occurs when the **potential gradient** exceeds a certain value but is not sufficient to cause sparking

CORONA TUBE. A **gas discharge tube** employing a **corona discharge,** used as a voltage reference tube.

CORONA VOLTMETER. See **voltmeter, corona.**

COROSIL. Trade name for an oriented silicon-iron magnetic alloy.

CORRECTION. The quantity which is added to a calculated or observed value to obtain the correct value. The correction is the negative of the **error.**

CORRECTION TIME. The time required for the **controlled variable** in an **automatic controller** to reach and stay within a predetermined band about the **control point** following any change of the independent variable or operating condition.

CORRECTION TO VACUUM. The correction of wavelengths or of the speed of light as measured in air to the appropriate values *in vacuo.* The **index of refraction** for air is about 1.000225 but is dependent on the density of the air.

CORRELATION COEFFICIENT. A measure of the dependence of one quantity on another.

CORRELATION ENERGY. The energy associated with the correlation effect in a metal, i.e., the tendency for electrons to keep apart, and hence for the positions of any two not to be entirely independent. It represents a correction to a naive calculation of **Coulomb energy.**

CORRESPONDENCE PRINCIPLE. The principle that in the limit of high **quantum numbers** the predictions of quantum theory agree with those of classical physics.

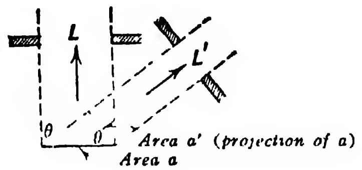
CORRESPONDING STATES, LAW OF. If any two or more substances have the same **reduced pressure** (the same fraction or multiple of their respective critical pressure) and are at equal **reduced temperature** (the same fraction or multiple of their respective critical temperature), their **reduced volumes** should be equal. These substances are said to be in corresponding states. (See also **critical state.**)

CORTI, ORGAN OF. A center of nerve terminals located in the inner ear, adjacent to the **basilar membrane.**

COSET. If X is an element of a **group** G, not contained in one of its **subgroups** H, then the set of elements HX is called a right coset and XH is a left coset. Cosets are not groups because they do not contain E, the unit element. They are called in German, however, "Nebengruppen."

COSINE EMISSION LAW. A law relating to the emission of **radiation** in different directions from a radiating surface. If a small, white-hot metal plate is viewed from a great distance, its apparent candle power, measured by a photometer, is greatest when it is perpendicular to the line of sight, and reduces to practically zero when it is turned edgewise. If the observer now moves nearer, he finds that this change is due to the smaller angle subtended by the surface, that is, the smaller cross-section of the beam proceeding from it in his direction; and that the apparent **brightness** of the surface is the same however it is turned. To apply this, let the radiating surface, of area a, be emitting a luminous **flux** L (lumens) in the normal direction (see figure), and, in any other direction making an angle θ with the normal, the smaller quantity L'. Then since the apparent brightness is unchanged, $L'/a' = L/a$. This gives L'/L

$= a'/a$. But $a'/a = \cos\theta$, hence $L' = L \cos\theta$; which means that the energy emitted in any direction is proportional to the cosine of



the angle which that direction makes with the normal. This is the "cosine emission law" of Lambert. It applies to thermal radiation as well as to light, and to diffusely reflected as well as directly emitted radiation. The law is true only for a perfectly diffusing surface, strictly, for a **black body**, but it is a good approximation to the behavior of many surfaces.

COSINE WINDING. See **winding, cosine.**

COSMIC RADIATION, CASCADE THEORY OF. See **cascade theory (of cosmic radiation.)**

COSMIC-RAY DECAY ELECTRONS. Electrons in the soft component of **cosmic rays** which originate from the decay of **mesons**.

COSMIC-RAY KNOCK-ON ELECTRONS. Electrons in the soft component of **cosmic rays** which originate in the direct impact of fast **mesons** with the orbital electrons of the oxygen and nitrogen atoms of the atmosphere.

COSMIC-RAY MESONS OR MESOTRONS. Any of several elementary particles found in cosmic radiation. They may be charged with either sign, or neutral, and are characterized by masses intermediate between that of the electron and the proton. They are unstable, with mean lives ranging from 10^{-14} seconds to 10^{-6} seconds. (See **meson.**)

COSMIC-RAY METER, MILLIKAN. A device consisting of an **ionization chamber** and quartz-fiber **electroscope** used to record the intensity of cosmic radiation.

COSMIC-RAY SHOWER. A phenomenon characterized by the simultaneous appearance of a number of downward-directed, light, ionizing particles, sometimes accompanied by photons, and having a common ultimate origin in an event caused by one cosmic ray.

COSMIC-RAY TRACKS, HEAVY. Tracks found in **cloud chambers** and emulsions exposed to cosmic radiation at very high altitudes. They are due to relatively heavy particles with atomic numbers ranging from 2 to 41.

COSMIC RAYS. A highly penetrating radiation apparently reaching the earth in all directions from outer space. The existence of this radiation was first suspected from the discharge of electroscopes in air free from all known ionizing influences, the rate of discharge increasing as the electroscope was carried to higher altitudes. (See **ionized gases.**) The atmosphere apparently absorbs a measurable portions of the rays, but traces of their effect persist even at depths of many feet below water or below the ground. Professor R. A. Millikan and his associates, who have studied the distribution and absorption of the rays very thoroughly, find that the rays are of nearly the same intensity from all parts of the celestial sphere, and that, as they proceed through an absorbing medium, they show evidence of unequal absorption rates. Experimental observations show that the cosmic rays entering our atmosphere are almost entirely composed of positively-charged atomic nuclei. About two thirds of these so-called primary cosmic rays are protons, and the other third (by mass) are about 90 per cent α-particles and 10 per cent heavier nuclei like carbon, nitrogen, oxygen, iron, etc. Upon entering the atmosphere, a high-energy primary particle soon collides with another atomic nucleus, splitting one or both particles into a number of smaller nuclear fragments, each one of which carries away some of the primary's energy. These high-speed particles in turn collide with other nuclei, further dividing their energy to produce other high-speed particles. All of these with the exception of the primary particle are called secondary cosmic rays.

Mesons of various kinds are present in cosmic rays, being formed most generally by collision of primary cosmic rays with air nuclei, high in the atmosphere. In these collisions positively and negatively charged π-mesons are produced, along with neutral π-mesons, and other nuclear particles, as stated above. The charged π-mesons decay principally into charged μ-mesons and **neutrinos**; and the μ-mesons decay in turn into

electrons and neutrinos. The uncharged π-mesons decay into **γ-rays,** which create in the upper atmosphere cascade showers of electrons by electron **pair-production** and **bremsstralung.**

COSMIC RAYS, ALTITUDE EFFECT ON. The intensity of **cosmic rays** as a function of altitude shows a maximum at a distance below the top of the atmosphere corresponding to a pressure of about 45 mm Hg. This maximum is due to the interaction of primary cosmic ray particles of extremely high energies with atomic nuclei in the top layer of the atmosphere.

COSMIC RAYS, EAST-WEST EFFECT ON. The east-west asymmetry in the number of charged cosmic ray particles observed on the earth caused by the deflection of the cosmic rays by the earth's magnetic field in combination with the rotation of the earth from west to east.

COSMIC RAYS, LONGITUDE EFFECT ON. The variation in cosmic ray intensity along the equator as a function of longitude. It may be interpreted as an indication that the earth's magnetic field, even at great heights, is not symmetrical.

COSMIC RAYS, MAGNETIC LATITUDE EFFECT. The variation in cosmic ray intensity with magnetic latitude, caused by the deflection of charged cosmic ray particles by the earth's magnetic field.

COSMIC RAYS, RELATION TO NEUTRONS AND OTHER PARTICLES. Neutrons in the atmosphere are probably the result of interactions between cosmic ray particles and atomic nuclei in the atmosphere.

COSMIC RAYS, PRIMARY. See **cosmic rays.**

COSMIC RAYS, SECONDARY. See **cosmic rays.**

COSMIC RAYS, SOFT COMPONENT OF. That portion of cosmic radiation which is absorbed in a moderate thickness of an absorber (usually 10 cm of lead). It consists mainly of **electrons, positrons,** and **photons,** but contains some slow **mesons,** slow protons, and other heavy particles often present in cosmic radiation. (See **cosmic rays.**)

COSMOLOGICAL CONSTANT. Coefficient Λ of the extra term added to the **Einstein law of gravitation** to make it

$$R_{\mu\nu} + \Lambda g_{\mu\nu} = -8\pi T_{\mu\nu}.$$

Introduced by Einstein in order that the proper pressure

$$\frac{1}{8\pi}\left(\Lambda - \frac{1}{R^2}\right)$$

be positive for an **Einstein universe** of radius R.

COSMOLOGICAL MODELS. Constructs of the universe as a whole; specifically, models of the universe based on the **Einstein law of gravitation.** (See **Einstein universe; de Sitter universe; expanding universe; continuous creation hypothesis.**)

COSMOTRON. A particle accelerator capable of accelerating particles to energies of billions of electron volts; specifically the proton accelerator at Brookhaven National Laboratory, Long Island, N. Y.

COTTON-MOUTON EFFECT. A dielectric placed in a magnetic field may become **double-refracting** with retardation δ of the **ordinary ray** over the **extraordinary ray** given by

$$\frac{\delta}{\lambda} = \frac{l(n_e - n_o)}{\lambda} = C_m l H^2$$

in which C_m is the Cotton-Mouton magnetic birefringence constant, l is the distance in the dielectric traversed by the light and H is the magnetic field strength. This is not the magnetic **Kerr effect** which is a rotation of the plane of polarization.

This effect is some thousand times greater than the **Voight effect** and is not related to the **Zeeman effect.**

COTTRELL HARDENING. Impurity atoms differing in size from those of the solvent can relieve hydrostatic stresses in a crystal by migrating to the **dislocations** about which they cluster and form an **atmosphere.** The dislocations are thus locked, and the material cannot yield readily to applied stress.

COTTRELL LOCKING. The mechanism by which an **atmosphere** of impurity atoms can prevent the movement of a **dislocation** line.

COTTRELL METHOD. See **boiling point, methods of determining elevation of.**

COUETTE FLOW. A two-dimensional steady flow without pressure gradient in the direction of flow and caused by the tangential movement of the bounding surfaces. The only practicable type is the flow between concentric rotating cylinders, although the flow between parallel planes with uniform relative velocity is used in the elementary discussion of **viscosity.**

COULOMB. A unit of electrical charge, abbreviation coul or Cb.

(1) The absolute coulomb is defined as the amount of electrical charge which crosses a surface in one second if a steady current of one absolute **ampere** is flowing across the surface. The absolute coulomb has been the legal standard of quantity of electricity since 1950.

(2) The International coulomb, the legal standard before 1950, is the quantity of electricity which, when passed through a solution of silver nitrate in water, in accordance with certain definite specifications, deposits 0.00111800 gm of silver. 1 Int. coul = 0.999835 abs. coul.

COULOMB DEGENERACY. Identity of the energy levels of a charged particle bound in a Coulomb field for different values of the orbital angular momentum, provided that the principal quantum number and spin state is the same, e.g., the $2S_{\frac{1}{2}}$ and $2P_{\frac{1}{2}}$ states of the hydrogen atom. (See **Lamb shift.**)

COULOMB ENERGY. That part of the **binding energy** of a solid associated with the electrostatic interaction of the **ions** and electrons. In the case of **metals,** where the electrons are not localized on the ions, this energy has presented serious problems, which have to some extent been overcome by the **Bohm and Pines method.**

COULOMB LAW (ELECTROSTATICS). The force between two point charges in free space is a pure attraction or repulsion, and is given by

$$F = \frac{q_1 q_2}{\epsilon_0 r^2}$$

where q_1, q_2 are the magnitudes of the charges, r is their separation, and ϵ_0 is a constant of nature. The numerical value of ϵ_0 depends upon the system of units used (see **electric constant**). When the charges are immersed in a homogenous medium, which extends to distances much greater than r in all directions

$$F = \frac{q_1 q_2}{\epsilon r^2}$$

where ϵ is the **permittivity,** or absolute dielectric constant of the medium.

COULOMB LAW (MAGNETISM). The force between two **magnetic poles** is given by

$$F = \frac{\mu p_1 p_2}{r^2}$$

where μ is the absolute **permeability** of the intervening medium. (Contrast **Coulomb law (electrostatics)** wherein the **dielectric constant** of the medium occurs in the denominator.) Because isolated magnetic poles do not exist, the law is a highly artificial construct. It is now largely replaced by laws of interaction between currents (see **Ampere law; Biot-Savart law**) combined with the deflection of a magnetic dipole.

COULOMBMETER OF COULOMETER. An electrolytic cell used for the measurement of the quantity of electricity passing through a circuit; also called **"voltameter."** The international **coulomb** (and **ampere**) are based on the amount of silver deposited in the electrolysis of a silver nitrate solution.

COUNT (RADIATION MEASUREMENTS). (1) In a radiation **counter,** a single response of the counting system. See also **count, tube.** (2) The external indication of a device designed to enumerate ionizing events. It may refer to a single detected event or to the total registered in a given period of time. The term is loosely used to designate a disintegration, ionizing event or voltage **pulse.**

COUNT, BACKGROUND. (1) In a radiation **counter,** a count caused by radiation coming from a source other than that being measured. (2) The totality of background counts as defined in (1).

COUNTER. (1) A device for counting **ionizing events.** The term may refer to a complete instrument or to the detector, usually a

device of the Geiger or scintillation type. (2) A device capable of changing from one to the next of a sequence of distinguishable states upon each receipt of a discrete input signal. The term counter is in some cases used to mean accumulator. (3) In mechanical analog-computers, a means for measuring the angular displacement of a shaft.

COUNTER, BORON. A **counter** filled with BF_3 and/or having electrodes coated with boron or boron compounds used for detecting slow neutrons by the (n,α) reaction of B^{10}.

COUNTER CHAMBER, CYLINDRICAL. A **counter** chamber consisting of a cylinder acting as one electrode and fine wire coaxial with the cylinder acting as the other electrode. The cylinder is usually the cathode, and the wire the anode.

COUNTER CHAMBER, PARALLEL-PLATE. A **counter** chamber with plane parallel electrodes.

COUNTER CHARACTERISTIC CURVE. The curve of the counting rate of a counter of the Geiger type, against applied voltage, all pulses counted being greater than a certain minimum size, determined by the sensitivity of the receiving circuit. (See **counter plateau; counting rate curves.**)

COUNTER, COINCIDENCE. An arrangement of **counters** and circuits which records the occurrence of **counts** in two or more detectors simultaneously or within an assignable time interval.

COUNTER, CRYSTAL. A **counter** utilizing one of several known crystals which are rendered momentarily conducting by ionizing events.

COUNTER DEAD TIME. In a radiation **counter,** the time from the start of a counted **pulse** until a succeeding pulse can occur. (See also **counter recovery time.**)

COUNTER EFFICIENCY. Of a radiation **counter** tube, the probability that a tube count will take place with a specified particle or quantum incident in a specified manner.

COUNTER ELECTROMOTIVE FORCE. See **electromotive force, counter.**

COUNTER, EXTERNALLY-QUENCHED. A radiation **counter** that requires the use of an external quenching circuit to inhibit **reignition.**

COUNTER, FIELD EMISSION IN. The emission of an electron from the surface of the cathode of the **counter** under the influence of the field of an approaching ion. The ion is then neutralized by the electron.

COUNTER FILLING SYSTEM. A system consisting of a gas and/or vapor reservoir, a manifold for attaching **counters,** and a vacuum system, used for the evacuation and filling of the **counter tubes.**

COUNTER, GAS. A radiation **counter** in which the sample is prepared in the form of a gas and introduced into the **counter tube** itself.

COUNTER GAS AMPLIFICATION. In **counter** terminology, the ratio of the charge collected to the charge liberated by the **initial ionizing event.**

COUNTER, GAS-FILLED. A gas tube, in a radiation **counter,** used for the detection of radiation by means of gas ionization.

COUNTER, GAS FLOW. A radiation **counter** in which an appropriate atmosphere is maintained in the **counter tube** by allowing a suitable gas to flow slowly through the volume.

COUNTER, GEIGER. (1) A radiation **counter** designed to operate in the **Geiger region.** (2) A radiation counter having a point or small sphere as its central electrode. This usage is obsolescent. (See **counter, point.**)

COUNTER, GEIGER REGION OF. See **Geiger region of a radiation counter.**

COUNTER, GEIGER THRESHOLD OF. See **Geiger threshold of a radiation counter tube.**

COUNTER, INITIAL IONIZING EVENT. See **initial ionizing event.**

COUNTER LIFE (TIME). The life or lifetime of a radiation **counter** tube is the number of counts which that counter tube is capable of detecting before becoming useless due to internal failure for any reason (e.g., gas

decomposition or wire pitting, etc.). The life is not a time but a measure of the amount of use.

COUNTER, LOCALIZATION OF DISCHARGE IN. The discharge in the **Geiger region** of a radiation **counter** normally spreads the entire length of the central wire in both **non-selfquenching** and **selfquenching counters.** A reduction in the field near the central wire by some artificial means, such as the presence of an insulating head, will interrupt or localize the spread of the discharge in a selfquenching counter. This is not the case in non-selfquenching counters since photoelectrons from the cathode spread the discharge beyond the obstacle.

COUNTER OPERATING VOLTAGE. The voltage across a radiation **counter,** when operating, measured between the anode and the cathode.

COUNTER OVERSHOOTING. A radiation **counter** is said to overshoot if the change in potential of the wire is greater than the **counter overvoltage.**

COUNTER OVERVOLTAGE. In a radiation **counter,** the amount by which the applied voltage exceeds the **Geiger-Mueller threshold.**

COUNTER, PARALLEL-PLATE. A radiation **counter** using parallel plate electrodes.

COUNTER, POINT. A radiation **counter,** in which the central electrode is a point (Geiger counter) or a small sphere (Geiger-Klemperer counter).

COUNTER PLATEAU. The region of the **counter characteristic curve** in which the counting rate is substantially independent of voltage. The **counter** is normally operated in this region.

COUNTER, PROPORTIONAL. A radiation **counter** designed to operate in the **proportional region.**

COUNTER, PROPORTIONAL, FOR HEAVY (α AND p) PARTICLES. A radiation **counter** operated under conditions such that the **pulse** produced is proportional to the amount of ionization created by the incident particle. It can thus be used to discriminate heavy particles (α-particles, protons, and deuterons) from β-rays and γ-rays; it can also be used to obtain the energy spectrum of the incident particles.

COUNTER, PROPORTIONAL, FOR NEUTRONS (FAST). A radiation **counter** containing methane or other hydrogenous gas or vapor together with a noble gas such as argon. Fast neutrons collide with hydrogen nuclei in the methane and give up their energy to the latter. These recoil protons then ionize the argon to produce a **pulse.**

COUNTER, PROPORTIONAL, FOR NEUTRONS (SLOW). A radiation **counter** containing a gas (normally boron trifluoride) which produces α-particles through the reaction

$$n + {}_5B^{10} \rightarrow {}_2He^4 + {}_3Li^7 + Q.$$

The α-particle and Li^7 nucleus then produce an **ionization pulse** in the boron trifluoride gas. The reaction has a **cross-section** which is inversely proportional to the velocity of the incident **neutron,** hence the counter is used for the detection of slow (thermal) neutrons.

COUNTER RECOVERY TIME. In a radiation **counter,** the minimum time from the start of a counted **pulse** to the instant a succeeding pulse can attain a specific percentage of the maximum value of the counted pulse.

COUNTER REIGNITION. A process by which multiple counts are generated within a **counter** by atoms or molecules excited or ionized in the discharge accompanying a tube **count.**

COUNTER RESOLVING TIME. The minimum time interval between **counts** that can be detected. The word may refer to an electronic circuit, to a mechanical recording device, or to a radiation **counter.** In the latter case, this quantity pertains to the combination of tube and recording circuit.

COUNTER, SCINTILLATION. A device consisting of any of several transparent **phosphors** together with a **photomultiplier tube** which detects ionizing particles or radiation by means of the light flash emitted when the radiation is absorbed in the phosphors. Commonly-used phosphors are zinc sulfide, **calcium tungstate, stilbene, anthracene, naphthalene, or thallium-activated sodium iodide.**

COUNTER, SELF-QUENCHED. A radiation **counter** in which **reignition** of the discharge is inhibited by internal processes.

COUNTER SPURIOUS TUBE COUNTS. Counts in radiation **counter tubes** other than background counts and those caused by the source measured. Spurious counts are caused by failure of the quenching process, electrical leakage, and the like. Spurious counts may seriously affect measurement of background counts.

COUNTER STARTING POTENTIAL. The voltage which must be applied to a radiation **counter** of the Geiger type to cause it to count, with the particular recording circuit which may be attached. The potential is not necessarily the same as, and generally is not equal to, the **Geiger-Mueller threshold** although there is some usage of the term "threshold" to denote starting potential

COUNTER, "THIN-WINDOW," "THIN-WALL." A radiation **counter** in which a portion of the enclosure is of low absorption to permit the entry of short-range radiation.

COUNTER TIME LAG (STATISTICAL). The time between the occurrence of the **primary ionizing event** and the occurrence of the **count** in the **counter.**

COUNTERBALANCING. Counterbalancing means simply the application of extra **mass** to a system in order to produce balance for the system as a whole, and to offset the unbalance arising from some particular part Rotating machinery, especially high-speed machinery, needs to be counterbalanced if the center of gravity of the rotating mass does not lie on the axis of rotation Hoists are frequently counterbalanced so that a descending weight will supply some of the energy required for hoisting the non-useful load. Numerous examples of counterbalancing will be found in everyday practice, but those cases associated with the counterbalancing of high-speed rotating machinery are the most imperative of solution.

COUNTERPOISE. A system of wires or other conductors, elevated above and insulated from the ground, forming a lower system of conductors of an **antenna.**

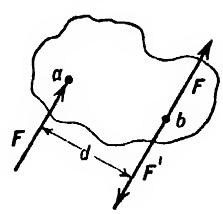
COUNTING CIRCUIT. A **scaling circuit.**

COUNTING RATE. The average rate of occurrence of ionizing events as observed by means of a counting system.

COUNTING-RATE CURVES. A curve of counting rate vs. applied voltage in a radiation **counter** generally shows an initial sharp rise at the **threshold voltage,** a more-or-less flat region (constant count rate) known as the plateau, and then a sudden sharp rise. The **counter** is usually operated in the plateau region.

COUNTING-RATE METER. A device which gives a continuous indication of the average rate of **ionizing events.**

COUPLE. As a usual thing the action of two forces on a body can be duplicated by a single force, equal to their **resultant,** acting at their **center of pressure.** Two parallel forces of equal magnitude but opposite direction cannot be reduced to a single force unless they are acting along the same line. They form a couple The effect of a couple upon a body is independent of the location of that couple with respect to the body. The net action of several couples all in the same plane on a body is equal to the algebraic sum of the moments of the couples, the sign being determined from the direction of rotation which the couple tends to give The moment of a couple is the product of the perpendicular distance between the forces and one of the forces. The action of any force, acting at any particular point on a body, upon another point lying in the plane of the force can be resolved into another force of the same magnitude acting at the desired point plus a couple. For example, let F be any force acting at point a, and b any other point at distance d from the



line of action of F. At point b place two equal and opposite forces F and F' which are parallel to the direction of the original force F. Then F' at b and F at a form a couple Fd, leaving F which acts through point b. The effect on point b of the latter force and the couple is the same as the effect of the original

force F acting at a. Thus it is seen that it is possible to replace a force acting at a with an equal force acting at b, and the couple Fd, where d is perpendicular distance from b to the force F in its original position The distance d is called the arm of the couple.

COUPLE, ARM OF (MOMENT ARM). The perpendicular distance between the lines of action of the two forces which constitute a **couple.**

COUPLE, MOMENT OF. The product of the force and the **arm** of a **couple.**

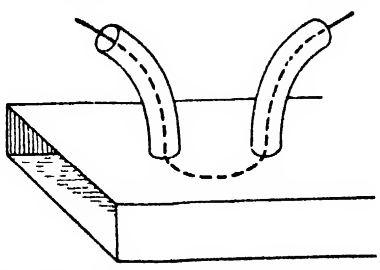
COUPLE, THEOREMS ABOUT. (1) The moment of a **couple** has the same value when moments of each force are taken about any axis perpendicular to the plane of the couple (2) A rigid body acted upon by a couple is in translational equilibrium, but not rotational equilibrium (3) A system of forces acting on a rigid body can be replaced by a single force acting at an arbitrary point of the body and a couple whose axis is parallel to the line of action of the force.

COUPLED CIRCUIT. See **circuit, coupled.**

COUPLED OSCILLATOR. See **oscillator, coupled.**

COUPLER, BETHE - HOLE DIRECTIONAL. A directional coupler (see **coupler, directional**) in which directivity is obtained by the simultaneous use of magnetic and electric coupling from the main line to the auxiliary line Coupling takes place through a hole in a broad face common to the two guides, the electric and magnetic coupling are made equal by rotating the auxiliary guide about the coupling hole.

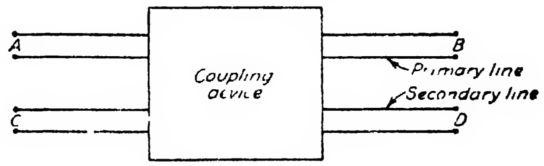
COUPLER, CAPACITANCE-LOOP DIRECTIONAL. A combined magnetic-electric, field-coupling, directional coupler in which a



Capacitance-loop directional coupler (By permission from "Microwave Theory and Techniques" by Reich et al., Copyright 1953, D. Van Nostrand Co., Inc.)

coupling link, short in length compared to a quarter wavelength, is placed lengthwise in a **waveguide.** At frequencies remote from the guide cutoff frequency, this type of coupler has little frequency sensitivity. (See **coupler, directional.**)

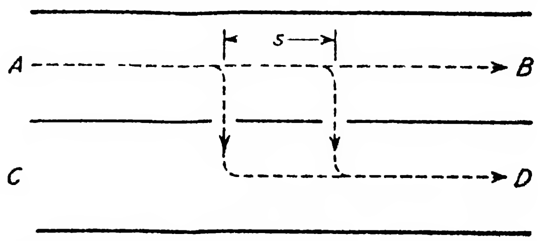
COUPLER, DIRECTIONAL. A directional coupler is a junction between four pairs of terminals, as shown in the figure, having such



Basic directional coupler (By permission from "Microwave Theory and Techniques" by Reich et al., Copyright 1953 D Van Nostrand Co, Inc)

characteristics that there is free transfer of power, without reflection between terminals A and B and no transfer of power between terminals A and C or between terminals B and D Thus an indication of power at point D indicates that power is flowing from A to B while an indication at C indicates power flow from B to A The coupling factor is defined by the relationship: coupling factor = $10 \log_{10} (P_A/P_D)d_0$, while the directivity is defined by the equation: directivity = $10 \log_{10} (P_D/P_C)d_0$.

COUPLER, DIRECTIONAL, TWO-HOLE. A type of directional coupler operating upon the antenna-array principle It consists of two sections of **waveguide** with a common side wall (wall parallel to the electric field) in which are two holes spaced longitudinally by the distance S Waves traveling from A



Top view of 2-hole coupler (By permission from "Microwave Theory and Techniques" by Reich et al., Copyright 1953, D Van Nostrand Co, Inc)

to D through the two holes arrive in phase, and reinforce each other, while the waves arriving at C have a phase difference, which causes cancellation. Because of the depend-

ence of the amount of phase shift upon the length S, this coupler is frequency-sensitive. (See **coupler, directional.**)

COUPLER, SCHWINGER. A "reverse-coupling" type of directional coupler (see **coupler, directional**) in which coupling is between the longitudinal magnetic field in one guide, and the transverse magnetic field in the other. Variation of directivity with frequency is small in this type of coupler.

COUPLING. (1) An interaction between systems, or between properties of a system. When there is little interaction, the coupling is sometimes said to be loose; with considerable interaction, it is called tight. (2) In induction heating usage and other induction apparatus, the percentage of the total magnetic flux produced by an inductor which is effective in heating a load or charge.

COUPLING APERTURE (COUPLING HOLE, COUPLING SLOT). Aperture in wall of **waveguide** or **cavity resonator** designed to transfer energy to or from an external circuit.

COUPLING CASES. The different angular momenta in the molecule—electron spin, electronic orbital angular momentum, angular momentum of nuclear rotation—form a resultant that is always designated **J**, as in the total angular momentum of an atom (in both cases disregarding nuclear spin). If the spin **S** and the orbital angular momentum **Λ** of the electrons are zero—that is, if we have a $^1\Sigma$ state—the angular momentum of nuclear rotation is identical with the total angular momentum **J**. In all other cases one must distinguish different modes of coupling of the angular momenta, as was first done by Hund. For detailed discussion of the Hund coupling cases, see Herzberg, *Spectra of Diatomic Molecules*, Second Ed. (Van Nostrand, New York, 1950).

COUPLING CHOKE. A coupling method for electronic amplifiers in which the load impedance for a given stage is a **choke coil** or inductance. (See **coupled circuit.**)

COUPLING CONSTANT. A number assigned, especially in the **meson theory of nuclear forces** and **β-decay theory,** as a measure of the strength of the interaction between the particles involved, by analogy with the electric charge which is the coupling constant between electrons and radiation. In a field theory, the total energy operator can be written as $H = H_0 + H'$, where H_0 represents the energy of the matter plus the energy of the radiation (the term radiation used here in the general sense, and covers for example, the electron-neutrino field in the case of β-decay) and H' represents the interaction energy. Assuming that H' is proportional to a matrix element, or component thereof M, of simple form: $H' = gM$, the numerical factor g is called the coupling constant. Transition probabilities are proportional to g^2 as well as M^2. (See **Fermi constant.**)

COUPLING, CRITICAL. See **critical coupling.**

COUPLING, DIRECT. A coupling method for electronic amplifiers which extends the frequency response down to zero frequency or d-c. This is achieved by connecting the output of one stage to the input of the other directly or through some non-frequency-sensitive element, such as a resistor or battery.

COUPLING, *j-j*. The interaction between two or more particles, all exhibiting spin-orbit coupling. (See **coupling, spin-orbit.**)

COUPLING, LS-. See **coupling, Russell-Saunders.**

COUPLING LOOP. A device for coupling an external circuit to a **waveguide** or **resonator.** It consists of a small loop placed at or near a point of high magnetic field strength in the guide or resonator, and turned in such a position that its plane is normal to the flux lines. It is designed to transfer energy to or from the external circuit.

COUPLING, POSITIVE. The **coupling** (or **mutual inductance**) between a pair of coils may be either positive or negative according to the choice of reference direction in the corresponding **meshes.** If an increasing current in one coil induces a voltage in the other, having the same sense as an increasing current in the second coil itself would produce, the mutual inductance is positive.

COUPLING PROBE. A device for coupling an external circuit to a **waveguide or resonator.** It consists of a **probe** parallel to the electric field of the guide or resonator at or near a point where the electric field has its

maximum value. It is designed to transfer energy to or from the external circuit.

COUPLING, PSEUDO-SCALAR. See **pseudo-scalar coupling.**

COUPLING, PSEUDO-VECTOR. See **pseudo-vector coupling.**

COUPLING, RESISTANCE - CAPACITANCE. A coupling method used in electronic amplifiers which employs resistance elements for the **load impedance** of the stages. A capacitor connects the output of one stage to the input of the next for a-c and transient signals without disturbing the d-c operating points of either stage. (See **coupled circuit.**)

COUPLING, RUSSELL-SAUNDERS. The interaction between the resultant orbital angular momenta and the resultant intrinsic angular momenta (or spins) of two or more particles. The orbital angular momentum and the spin angular momentum vectors of the individual particles are added separately to obtain a resultant orbital and a resultant spin angular momentum vector. The two resultants are then combined vectorially to obtain a series of allowed total angular momentum vectors.

COUPLING, SPIN-ORBIT. The interaction between the intrinsic and orbital angular momentum of a particle. In an atom exhibiting spin-orbit coupling, the total angular momentum $\mathbf{J}$ is the vector sum of the angular momenta $\mathbf{j}_i$ of the individual electrons.

COUPLING, TRANSFORMER. Cascade, electronic-amplifier coupling in which the load impedance of one stage is the primary of a transformer whose secondary drives the grid of the succeeding stage. (See **coupling circuit.**)

COUPLING, TRANSITION TYPES. Since *LS*-coupling and *jj*-coupling (see **coupling, Russell-Saunders,** and **coupling, *jj*-**) represent two extremes, transition cases occur. Thus, as the value of *Z* is increased in the elements of Group IV (C, Si, Ge, Sn, Pb) the coupling changes from pure *LS* in the first two members to a type which is closer to *jj*-coupling in the case of Pb.

COUPLING, WEAK. Interaction between two particles by means of one or more fields which is such that the **interaction energy** may be expanded in powers of a dimensionless parameter which is small compared with unity, e.g., coupling of charged particles with each other through an electromagnetic field, where the dimensionless parameter is the **fine-structure constant.**

COVALENCE. A chemical **linkage** in which the sharing of electrons occurs in pairs, each pair being equivalent to one conventional chemical bond. In the union there is a tendency for each atom to acquire an outermost layer of eight electrons. In most cases, each of the atoms joined by the bond furnishes one electron of the pair, although there are many exceptions (see **covalence, dative**). The term covalence is opposed to **electrovalence,** in which the atoms or radicals are joined by electrostatic forces due to the actual transfer of electrons from the field of one atom to that of the other. These differences in structure are accompanied by resulting differences in properties.

COVALENCE, DATIVE. A valence linkage between two atoms in which both the electrons forming a covalent bond are furnished by one of the atoms

COVALENT CRYSTAL. A crystal held together by covalent bonds (see **bond, covalent**), as, for example, diamond.

COVARIANT. See **tensor, covariant** and **covariant vector.**

COVARIANT EQUATION. Equation which retains its form under transformation to quantities measured by another observer; more particularly, under a **Lorentz transformation.**

COVARIANT VECTOR. Any set ϕ_μ of four functions of the coordinates x^μ which under a general coordinate transformation $x^\mu \longrightarrow x'^\mu$ becomes

$$\phi'_\mu = \sum_\nu \frac{\partial x^\nu}{\partial x'^\mu} \phi_\nu.$$

COVERSINE. If θ is an angle, coversine θ = covers $\theta = 1 - \sin\theta$.

COVOLUME. The correction term applied in certain **equations of state,** as in that of **van der Waals,** to correct the volume of the gas for *the effect of* the volume of the molecules. This term is not the molecular volume itself.

CPS EMITRON. A British **camera tube.**

CRAMER RULE. A means for solving a set of **linear simultaneous equations.** If they are

$$y_i = \sum_{k=1}^{n} A_{ik} x_k, \quad i = 1, 2, 3, \cdots, n$$

the solutions are

$$x_i = \frac{1}{|A|} (y_1 A^{1i} + y_2 A^{2i} + \cdots + y_n A^{ni})$$

where $|A|$ is the **determinant** of the coefficients of A_{ik} and A^{ki} is the **cofactor** of A_{ik}

CRATER LAMP. A **glow-discharge tube** having a solid cylindrical cathode with a conical or crater-shaped depression in one end The electrode design is such that the discharge takes place in the crater, producing a concentrated light source

CREATION HYPOTHESIS, CONTINUOUS. See **continuous creation hypothesis.**

CREATION OPERATOR. An operator which, applied to a state vector Φ_n describing a system in which n particles are present, yields a state vector Φ_{n+1} which describes the system with $(n + 1)$ particles present

CREEP. **Plastic** flow under constant **stress.** At low temperatures the creep rate is usually low, the strain being often found to vary as the logarithm of the time, but the effect increases rather rapidly with temperature The theory of creep is very incomplete

CREST FACTOR OF PULSE. See **pulse, crest factor of.**

CREST FACTOR OF A PULSE CARRIER. See **pulse carrier, crest factor of.**

CREST FORWARD ANODE VOLTAGE. See **anode voltage, peak forward.**

CREST INVERSE ANODE VOLTAGE. See **anode voltage, peak inverse.**

CRISPENING CIRCUIT, TELEVISION. A circuit for providing by non-linear means, a picture with greater definition without increased bandwidth

CRIT. The mass of fissionable material which, under a given set of conditions, is **critical.** Sometimes applied to the mass of an untamped critical sphere of fissionable material.

CRITH. A unit of mass equal to the weight in grams of one liter of hydrogen at standard temperature and pressure, 0 0906 g.

CRITICAL. In nuclear **reactor** technology, capable of sustaining (at a constant level) a chain reaction Prompt critical is capable of sustaining a chain reaction without the aid of delayed neutrons (See **neutrons, delayed.**)

CRITICAL ANGLE. See **total reflection.**

CRITICAL ASSEMBLY. An assembly of fissionable material plus **moderator** which is capable of maintaining a fission chain reaction at very low power level and which is used mainly to study the behavior of the fissionable material under various conditions of geometry, composition, etc

CRITICAL COEFFICIENT. An additive property of substances which is also a measure of the space actually occupied by the molecules and is proportional to the **critical volume.** It is expressed as the ratio between the critical temperature T_c and the critical pressure P_c, or

$$k = \frac{T_c}{P_c}.$$

(Some writers define the critical coefficient as the product $\cdot\, RT \dfrac{T_c}{P_c}$)

CRITICAL COMPOSITION. Systems, consisting of two liquid layers that are formed by the equilibrium between two partly-miscible liquids, frequently have a **consolute temperature** or a critical solution temperature, beyond which the two liquids are miscible in all proportions At this temperature, the phase boundary disappears and the two liquid layers merge into one The composition of the mixture at that point is called the critical composition There is, in some cases, a lower consolute temperature as well as an upper consolute temperature

CRITICAL COUPLING. In a tuned-primary tuned-secondary **transformer,** the degree of **coupling** which causes the maximum secondary current This condition also provides maximum flatness of the **passband.** If the primary and secondary are tuned to the same frequency, the condition for critical coupling is:

$$\omega M = \sqrt{R_p R_s}$$

where ω is the frequency in radians per second, M is the coefficient of coupling, and R_p and R_s are primary and secondary resistances, respectively (See **inductance, mutual.**)

CRITICAL DENSITY. The density of a substance which is at its **critical temperature** and **critical pressure.**

CRITICAL EQUATION. In nuclear reactor technology, an equation relating parameters of a **reactor** which must be satisfied for the reactor to be **critical.**

CRITICAL FIELD. (1) The magnetic field H_c below which the **superconducting transition** takes place at a given temperature Empirically, a relation is observed of the form

$$H_c = H_0\{1 - (T/T_c)^2\}$$

where H_0 is a parameter characteristic of the material, and T_c is the **critical temperature of the superconductor.** (2) Of a **magnetron,** the smallest theoretical value of steady magnetic **flux density,** at a steady anode voltage, that would prevent an electron emitted from the cathode at zero velocity, from reaching the anode

CRITICAL FREQUENCY (ELECTROMAGNETIC WAVE). The limiting frequency below which a magneto-ionic wave component is reflected by, and above which it penetrates through, an **ionospheric layer** at vertical incidence

CRITICAL GRID CURRENT. See **grid current, critical.**

CRITICAL GRID VOLTAGE. See **grid voltage, critical.**

CRITICAL HUMIDITY. The water content of the atmosphere at which the partial pressure of water vapor is equal to the saturation vapor pressure Condensation on suitable nuclei will occur when the humidity reaches or exceeds this value

CRITICAL INDUCTANCE. See **inductance, critical.**

CRITICAL MASS. The mass of fissionable material in a critical reactor (See **reactor, critical.**)

CRITICAL OPALESCENCE. The phenomenon produced when a homogeneous solution of two liquids at its **critical composition** is cooled from a temperature above its consolute temperature to one below that temperature This phenomenon consists of a bluish haze which is believed to be due to the scattering of light brought about by local variations of density within the liquid

CRITICAL PHENOMENA. The critical temperature, pressure, and volume

CRITICAL POINT. A point where two **phases,** which are continually approximating each other, become identical and form but one phase With a liquid in equilibrium with its vapor, the critical point is such a combination of temperature and pressure that the specific volumes of the liquid and its vapor are identical and there is no distinction between the two states The critical solution point is such a combination of temperature and pressure that two otherwise partially miscible liquids become **consolute.**

CRITICAL POINT, TERNARY. The point where upon adding a mutual solvent to two partially miscible liquids (as adding alcohol to ether and water) the two solutions become consolute and one phase results

CRITICAL POTENTIAL. In atomic physics the critical potential is used in general as a measure of the amount of energy necessary to raise an electron from a lower to a higher level The term 'potential" is used because the quantity of energy is measured by means of electrons accelerated by application of a known potential the energy of the electrons being given by the product of the accelerating potential and the electronic charge

Two kinds of critical potentials are the ionization potentials and the resonance potentials The ionization potential represents the work necessary to remove an electron from a normal atom, wherein the electron may be supposed to be in its lowest level, to an infinite distance so that a positively charged ion results The resonance potential is a measure of the work required to raise an electron from the lowest level to any other level, and therefore, there are first, second, etc **resonance potentials,** corresponding to the transfer of an electron from the lowest level to the next level, to the next-but-one level, etc. (See also **critical voltage.**)

CRITICAL PRESSURE. (1) The pressure of a vapor at its **critical point,** defined by

$$\left(\frac{\partial p}{\partial v}\right)_T = \left(\frac{\partial^2 p}{\partial v^2}\right)_T = 0.$$

(2) If a compressible fluid flows from a container through an orifice or other constriction, the volume flow depends on the pressure difference across the flow system only if the final pressure exceeds a fraction of the initial pressure. If either the initial or the final pressure is held constant, there is a critical pressure separating a regime of flow dependence on pressure difference from one of independence. The fraction depends on the nature of the fluid.

CRITICAL REGION. The region in the **diagram of state** of a substance in the neighborhood of the **critical point.**

CRITICAL SHEAR STRESS. The resolved shear stress which is required to initiate slip in a given crystallographic direction along a given crystallographic plane of a single crystal of a metal.

CRITICAL SIZE. Any one of a set of physical dimensions of the core and reflector of a nuclear **reactor** maintaining a critical chain reaction, the material and structure of the core and the reflector having been specified.

CRITICAL SOLUTION TEMPERATURE. For two partially miscible liquids, the composition of the two **conjugate solutions** approach each other with increasing temperature. At the critical solution temperature the two solutions have identical compositions and form one layer.

CRITICAL TEMPERATURE. (1) The maximum temperature at which a gas or vapor can be liquefied (by application of the critical pressure). Above this temperature the substance exists only as a gas. (2) Of a **superconductor,** the temperature T_C at which the **superconducting transition** takes place in zero magnetic field.

CRITICAL VELOCITY OF FLOW. If above a certain velocity of flow the nature of the flow changes qualitatively, the velocity is critical for the particular flow system. The criterion is always better expressed as a critical **Reynolds number, Mach number, Froude number** or whatever the appropriate non-dimensional parameter may be.

CRITICAL VOLTAGE (OF A MAGNETRON). The highest theoretical value of steady anode voltage, at a given steady **magnetic flux density,** at which electrons emitted from the cathode at zero velocity would fail to reach the anode. (See also **critical potential.**)

CRITICAL VOLUME. The volume occupied by unit mass, commonly one mole, of a substance at its **critical temperature** and **critical pressure.**

CRO. Abbreviation for **cathode-ray oscilloscope.**

CROOKES DARK SPACE. See **cathode dark space.**

CROOKES RADIOMETER. An apparatus for detecting small quantities of **radiant energy,** chiefly in the visible and infrared region of the **electromagnetic spectrum.** It consists of four arms, each terminating in a metallic disc, silvered on one side and blackened on the other, mounted on a shaft in an evacuated glass bulb. Upon incidence of radiation the assembly begins to rotate about the shaft. This instrument is not a measure of "light pressure." The radiation absorbed by the blackened sides of the discs causes those sides to be warmer than the polished sides. The remaining molecules of the gas rebound more rapidly from the warm sides, and hence exert a reactive force, which is larger if the molecules of residual gas have a **mean free path** which is large compared with the distance between the plates. In this instrument, the polished sides of the discs advance and the darkened sides retreat.

CROOKES TUBE. A gas-filled **discharge tube** with electrodes at the ends and a pressure of about 1 mm of mercury. When a high voltage direct potential is applied to the electrodes, the following appear in the tube. Starting at the anode (+ terminal) there is (1) a positive column, often striated, (2) the Faraday dark space, (3) the negative glow, (4) Crookes dark space, (5) cathode glow. The relative sizes of some of these may be changed greatly by changing the pressure in the tube. At quite high vacuum, the Crookes dark space fills almost the entire tube.

CROLITE. Trade name for a type of ferrite material.

CROSS BOMBARDMENT. A method of determination of the **atomic number** of a **radioelement,** by producing it by a number of different nuclear reactions. As an illustration, in order to determine the atomic number of a 47-day, β-activity **isotope** of iron produced by deuteron bombardment, cobalt oxide was treated with neutrons of medium energy. It was observed that a 47-day, β-activity developed, and that the isotope having this activity could be extracted by chemical methods for iron. It was evident, therefore, that deuteron bombardment of a stable isotope of iron, and neutron bombardment of a stable isotope of cobalt, produced the same radioisotope of iron.

CROSS-CONDUCTION. In a reversible **magnetic amplifier,** the simultaneous conduction or **gating** of half-wave elements connected in a mesh containing the a-c supply voltage but not the load.

CROSS COUPLING (IN A TRANSMISSION MEDIUM) A measure of the undesired power transferred from one channel to another.

CROSSFIRE. Interfering current in one signaling channel resulting from signaling currents in another channel.

CROSS-HAIR LINES. Fine lines (spider web, silk, fine metal wire, fine lines on a flat glass plate) placed at the exact position of the first real image in a telescope or microscope for the purpose of aiding in pointing the instrument at a particular point of the object.

CROSS-MODULATION. **Modulation** of a desired signal by an undesired signal

CROSSOVER FREQUENCY. (1) As applied to electric dividing **networks,** the frequency at which equal electric powers are delivered to each of the adjacent frequency channels when all channels are terminated in the loads specified. (2) The transition frequency in a two-channel **loudspeaker** system at which the low (woofer) and high (tweeter) frequency units deliver equal power.

CROSS POLARIZATION. The component of the **electric field vector** normal to the desired polarization component.

CROSS SECTION. From its original meaning of a section at right angles to an axis, the term cross section has been extended to mean a measure of the probability of a particular process. It is expressed in units of area, although it is not usually identical with the geometric cross section across which the process occurs. For a collision reaction between nuclear or atomic particles or systems, the cross section is an area such that the number of reactions occurring is equal to the product of number of target particles or systems multiplied by the number of incident particles which would pass through this area at normal incidence. If n_t is the number of target nuclei or other particles per unit area of a substance exposed to an incident beam consisting of n_0 particles, then $\sigma = N/n_0n_t$, where N is the number of reactions of a specified type. Nuclear cross sections include the cross section for **fission,** the cross section for slow neutron **capture,** the cross section for **Compton collision** and the cross section for **ionization** by electron impact.

CROSS SECTION, ACTIVATION. The **cross section** of formation for a particular radionuclide. It is most commonly used for neutron-induced reactions.

CROSS SECTION, CAPTURE. The **cross section** for radiative **capture.**

CROSS SECTION DETERMINATION, ACTIVATION METHOD. The determination of the thermal neutron absorption **cross section** of a substance by means of the measurement of the radioactivity of the product formed by the neutron absorption.

CROSS SECTION DETERMINATION, TRANSMISSION METHOD. The determination of absorption and scattering **cross section** by means of the measurement of the loss of intensity of the incident beam in passing through the substance.

CROSS SECTION, DIFFERENTIAL. The **cross section** for a nuclear process whereby an angle is specified (relative to the direction of incidence) for the emission of particles or photons per unit angle or per unit solid angle.

CROSS SECTION, DIFFERENTIAL SCATTERING. **Cross section** for **scattering** of a particle from its initial velocity to a new velocity, per unit solid angle per unit speed at the new velocity.

CROSS SECTION, IONIZATION. In general, the probability that a particle or photon traversing a gas, or other form of matter, will undergo an ionizing collision while passing through unit length of a volume just sufficient to contain one atom. The term is used especially in radiation **counter** technology, where it is a measure of the probability that an electron traversing a radiation counter will make an ionizing collision with one of the counter gas atoms. In the low voltage region the ionization cross section increases linearly with the electron energy.

CROSS SECTION, MACROSCOPIC. (1) **Cross section** per unit volume (preferred). (2) **Cross section** per unit mass or weight.

CROSS SECTION, MICROSCOPIC. Cross section per atom or molecule.

CROSS SECTION, STOPPING. The same as atomic stopping power. (See **stopping power, atomic.**)

CROSS SECTION, TOTAL. The cross section effective for removing an incident particle from a beam. It is the sum of the separate cross sections for all processes by which the particle can be removed from the beam. For example, the total cross section of an atom for a nuclear particle is essentially the total of the absorption and **scattering** cross sections; for a photon it is essentially the sum of the **Compton scattering, photoelectric** and **pair production** cross sections.

CROSS TALK. The sound heard in a receiver associated with a given telephone channel resulting from telephone currents in another telephone channel. In practice, cross-talk may be measured either by the loudness of the overheard sounds, or by the magnitude of the coupling between the disturbed and disturbing channels. In the latter case, to specify the loudness of the overheard sounds, the volume in the disturbing channel must also be given. (See also **magnetic printing.**)

CROSSED POSITION. When **nicol prisms** or other polarizing systems are set with their axes at right angles (crossed position) no light passes. For any optically active material placed between the two, a resulting rotation of the plane of polarization as produced by the first or polarizing nicol will permit some of the radiation to pass through the second or analyzing prism.

CROVA WAVELENGTH. That wavelength in the spectrum of a radiator at any given temperature T whose intensity i_λ varies at the same relative rate as does the intensity I of the total radiation. In mathematical form, that value of λ for which

$$\frac{di_\lambda/dT}{i_\lambda} = \frac{dI/dT}{I}.$$

"CROWN-OF-THORNS." See **magnetron, tuneable, methods of tuning.**

CRT. Abbreviation for **cathode ray tube.**

CRUNODE. See **node.**

CRYOGENIC SYSTEM. A system in which a local temperature lower than the surrounding temperature is produced.

CRYOHYDRATE. An **eutectic** system consisting of a salt and water, having a concentration at which complete fusion or solidification occurs at a definite temperature (eutectic temperature) as if only one substance were present.

CRYOHYDRIC POINT. The **eutectic point** in cases in which the system contains water.

CRYOMETER. A low-temperature thermometer.

CRYOSCOPE. An instrument for measuring the freezing or solidification point. The Hortvet cryoscope is used for the estimation of added water in milk from the lowering of the freezing point.

CRYOSCOPIC CONSTANT. A quantity calculated to represent the molal depression of the freezing point of a solution, by the relationship

$$K = \frac{RT_0^2}{1000l_f}$$

in which K is the cryoscopic constant, R is the **gas constant,** T_0 is the freezing point of the pure solvent, and l_f is the **latent heat of fusion** per gram. The product of the cryoscopic constant and the **molality** of the solution gives the actual depression of the freezing point for the range of values for which this relationship applies. Unfortunately, this range is limited to very dilute solutions, usually up to molalities of $\frac{1}{100}$.

CRYOSCOPY. Examination of the freezing points of solutions.

CRYOSTAT. A low-temperature **thermostat.**

CRYPTOCRYSTALLINE. Having a crystal form (see **crystallography**) that is "hidden" and difficult to recognize, so that the substance appears to be amorphous, e g , flint, jasper, etc.

CRYSTAL. A macroscopic sample of a solid substance exhibiting some degree of geometrical regularity, or symmetry, or capable of showing these properties after suitable treatment (e g., cleavage, etching, etc). Almost all pure elements and compounds are capable of forming crystals

A perfect crystal is one in which the **crystal structure** would be that of an ideal **space lattice.** No such crystals exist, all real crystals containing imperfections which have a strong influence on the physical properties of the crystal.

CRYSTAL ANALYSIS. See **crystal structure.**

CRYSTAL ANGLES. The characteristic constant angles between the faces of any given crystal form

CRYSTAL AXIS. See **crystallographic axes.**

CRYSTAL, BIAXIAL. A doubly refracting crystal which has two optic axes There are two directions parallel to which light travels with one definite velocity independent of its state of polarization Examples: mica, sulphur, turquoise

CRYSTAL, BIMORPH PIEZOELECTRIC. See **bimorph cell.**

CRYSTAL BLANK. The result of the final cutting operation on a **crystal slab.**

CRYSTAL CLASSES. See **symmetry classes.**

CRYSTAL-CONTROLLED TRANSMITTER. See **transmitter, crystal-controlled.**

CRYSTAL COUNTER. A device for detecting high energy particles by the pulse of current produced when a particle passes through a normally insulating crystal to which a potential difference is applied.

CRYSTAL, COVALENT. See **covalent crystal.**

CRYSTAL CUT. A plane section with two parallel, major surfaces cut in any orientation.

CRYSTAL CUT, AT-CUT. A quartz plate cut from a plane that is rotated about an X-axis so that the angle θ made with the Z-axis is approximately 35 5 degrees. It is characterized by a substantially-zero temperature coefficient at a temperature determined by the exact value of θ.

CRYSTAL CUT, BT-CUT. A quartz plate cut from a plane that is rotated about an X-axis so that the angle θ made with the Z-axis is approximately -49 degrees. It is characterized by an essentially-zero temperature coefficient

CRYSTAL CUT, X-CUT. A quartz plate obtained by cutting a slab from the mother-crystal normal to the X-axis (electric axis), with major surfaces parallel to the Y- and Z-axes. (See **piezoelectric phenomena.**)

CRYSTAL CUT, Y-CUT. A quartz plate obtained by cutting a slab from the mother-crystal normal to the Y-axis (mechanical axis), with major surfaces parallel to the X- and Z-axes (See **piezoelectric phenomena.**)

CRYSTAL CUT, Z-CUT. A quartz plate obtained by cutting a slab from the mother-crystal normal to the Z-axis (optical axis), with major surfaces parallel to the X- and Y-axes (See **piezoelectric phenomena.**)

CRYSTAL DETECTOR. A device consisting of a "cat's whisker" bearing on a semiconducting crystal, used in early radio sets. It depends for its action on the rectifying properties of the point contact, just as in the type-A transistor. (See **transistor, type A.**)

CRYSTAL DIODE. See **diode, crystal.**

CRYSTAL ELEMENTS. The angles, plus the **axial ratios** or **intercept ratios**, in terms of which the position of any crystal face may be described.

CRYSTAL, FACE-SHEAR. A piezoelectric crystal designed to oscillate in the face-shear mode of motion.

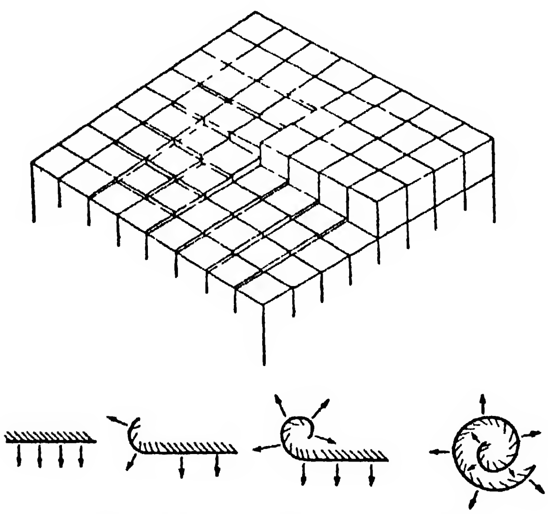
CRYSTAL FIELD. The electrostatic field acting locally inside a crystal as a consequence of the microscopic arrangement of atoms and ions in the **lattice.**

CRYSTAL, FLEXURE. A piezoelectric crystal designed to oscillate in the flexure mode of motion.

CRYSTAL FORM. See **crystallography.**

CRYSTAL FREQUENCY MULTIPLIER. (1) A quartz crystal made to oscillate in a harmonic mode to increase the frequency of oscillation without a decrease in crystal size. (2) A **semiconductor rectifier** used to rectify and thus, in the process, generate higher order harmonics of the fundamental voltage.

CRYSTAL GROWTH. The direct growth of an ideal perfect crystal is almost impossible, except at enormously high supersaturations, because of the difficulty of nucleating a new surface on a completed surface of the crystal. But, if there is a **screw dislocation** present, it is never necessary to start a new surface, and growth proceeds in a spiral fashion by the accretion of atoms at the edge of **growth steps.** The resultant **growth spirals** have been observed, and it is believed that most crystals grow in this manner.



Crystal growth (after F. C. Frank)

CRYSTAL HABIT. The external shape of a crystal, which depends on the relative development of the different faces, as well as upon the interfacial angles characteristic of the crystal.

CRYSTAL, HEMIHEDRAL. A crystal that has half of its faces developed.

CRYSTAL, HOLOHEDRAL. A crystal that has all of its faces developed.

CRYSTAL INDICES, MILLER. Three indices used to represent any crystal face in terms of the **crystallographic axes** and the **axial ratios.** These integers give the ratio of the intercepts of the **unit plane** to those of the particular face.

CRYSTAL INTERCEPTS. See **crystallographic parameters.**

CRYSTAL, IONIC. A crystal built up from a lattice of **ions** and bound together by the electrostatic attraction between them, e.g., NaCl.

CRYSTAL, ISOMORPHOUS. One of two or more crystals which are similar in crystalline form and in chemical properties and are related in chemical composition in that one or more of the atoms and radicals in one are of similar chemical type to the corresponding atoms or radicals in the other. Usually, one or more of their other atoms or radicals are identical.

CRYSTAL LATTICE. See **space lattice.**

CRYSTAL, LIQUID. A liquid having the optical properties of a crystal. Such liquid crystals are **uniaxial, anisotropic,** and also cloudy, and have a definite temperature (melting point) at which the crystalline optical properties and cloudiness disappear.

CRYSTAL, LONGITUDINAL. A piezoelectric crystal designed to oscillate in the longitudinal mode of motion.

CRYSTAL LOUDSPEAKER. See **loudspeaker, crystal.**

CRYSTAL MICROPHONE. See **microphone, crystal.**

CRYSTAL, MIXED. A crystal consisting of two or more chemical compounds, which may have the same positive radical or the same negative radical, and which, in their pure form, are isomorphous, i.e., have the same crystal form.

CRYSTAL MIXER. See **mixer, crystal.**

CRYSTAL, MOLECULAR. A crystal which is made up of inert gas atoms, or saturated molecules, bound together only by the **van**

der Waals forces between them, e.g., solid argon.

CRYSTAL MOMENTUM. An expression sometimes used for the quantity obtained by multiplying a **wave vector** by **Planck's constant,** h. It has the dimensions of momentum, but when it refers to an excitation or electron wave in a crystal there is no real momentum associated with it, and it is not necessarily conserved in a collision.

CRYSTAL, MOTHER. The raw material from which **piezoelectric devices** are prepared.

CRYSTAL, NEGATIVE. See **negative crystal.**

CRYSTAL OSCILLATOR. See **oscillator, crystal;** also **piezo-electricity** and **pyro-electricity.**

CRYSTAL OVEN. A temperature-controlled container for stabilizing the temperature and resonant frequency of a crystal used in a crystal-controlled **oscillator.**

CRYSTAL PARAMETERS. The lengths of the intercepts on the **crystallographic axes** of the **standard plane**—that is, the lengths of the sides of the **unit cell** of the lattice. In general, only the **axial ratios** can be determined directly.

CRYSTAL PHASES (α-, β-, γ-, ϵ-, η-, ETC.). Certain **alloy systems** may form different crystal structures, according to the relative proportions of the constituents for example Cu-Zn for which no less than five different phases are known In many cases the same **crystal structure** occurs with quite different constituent metals, so that it is often possible to use the one expression such, for example, as β-phase, to cover a wide variety of compounds all having the same basic structure. This effect is explained by the **Hume-Rothery rules.** Pure substances, as well as alloys, may exhibit more than one crystal structure, depending on temperature and past history. E g , cobalt, iron, titanium.

CRYSTAL PICKUP. An **electromechanical transducer** utilizing a **piezoelectric crystal** to effect the transformation from mechanical motion to an electrical effect. For example, many phonograph-pickups use crystals in this way.

CRYSTAL, PIEZOELECTRIC. A crystal of a substance having strong piezoelectric (see **piezo-effect**) properties cut in such a way that the coupling to some particular mechanical mode of the crystal is emphasized. Such crystals are valuable as electro-mechanical **transducers,** as in the crystal microphone. The sharpness of the mechanical resonance of a solid makes a crystal resonator one of the most stable of frequency standards when loosely coupled into an electronic circuit.

CRYSTAL PLANE. See **crystallography.**

CRYSTAL PULLING. A method of crystal growing in which the developing crystal is gradually withdrawn from a melt.

CRYSTAL RECTIFIER. See **rectifier, crystal.**

CRYSTAL, RESONANCE FREQUENCY OF. The frequency at which a **piezoid** has either a maximum or minimum impedance, depending upon whether parallel or series resonance is employed

CRYSTAL RESONATOR. See **piezoid, resonating.**

CRYSTAL SET. A radio receiver employing a crystal rectifier as a **rectifier demodulator.**

CRYSTAL SLAB. A relatively thick cut across a mother crystal from which **crystal blanks** are to be obtained by subsequent transverse cutting

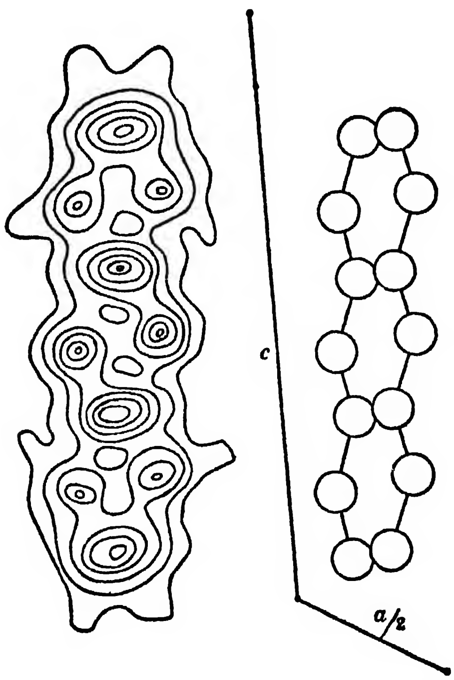
CRYSTAL-STABILIZED TRANSMITTER. See **transmitter, crystal-stabilized.**

CRYSTAL STRUCTURE. It was early suggested that the regular structure of crystals, embodied in the laws of **crystallography** could be explained if they were thought of as built up by the repetition of equal polyhedral cells, fitting together to fill space, each cell representing a characteristic group of particles, perhaps the atoms and molecules of the compound. A rough calculation showed that the spacing of these units in many ionic crystals might be of the same order of magnitude as the wavelengths of **x-rays,** as deduced from **quantum theory.** Von Laue suggested, and verified, that **diffraction** of the x-rays occurs when they are passed through a crystal, suitably oriented. This diffraction effect is characteristic of the type of crystal, and by observing the relative magnitudes and orienta-

tions of the various diffracted beams one has clues to the crystal structure.

Although it is easy to calculate the diffraction pattern for a given crystal structure, it is quite another matter to deduce the crystal structure directly from the diffraction pattern. The first step is to determine the spacing of the **atomic planes** from the **Bragg equation,** and hence the dimensions of the **unit cell.** Any special symmetry of the **space group** of the structure will be apparent from **space group extinction.** A **trial analysis** may then solve the structure, or it may be necessary to measure the **structure factors** and try to find the phases for a **Fourier synthesis.** Various techniques can be used, such as the **F^2 series,** the **heavy atom,** the **isomorphous series, anomalous atomic scattering, expansion** of the crystal and other **methods.** (See also **x-ray analysis.**)

CRYSTAL STRUCTURE-FOURIER SYNTHESIS METHOD. The intensity of the x-ray beam diffracted in a given direction by a crystal is a measure of the magnitude of one of the **Fourier components** of the electron



Electron density and projection of anthracene (after Robertson)

charge density in the crystal. If the sign of each component can also be estimated, or guessed, it is possible to construct a "contour map" of the electron density, showing the detailed structure. See figure.

CRYSTAL STRUCTURE—PHASE DETERMINATION BY CRYSTAL EXPANSION. An ingenious method for determining the relative phases of x-rays diffracted by a crystal, in which the crystal is expanded by being allowed to take up water, and the varying intensities of the different rays observed and interpreted. This method is particularly suitable for proteins.

CRYSTAL STRUCTURE—TRIAL ANALYSIS METHOD. Various possible crystal structures are proposed, and their **x-ray diffraction** patterns calculated, using the known **atomic structure factors,** and compared with the observed pattern, until a structure is found that fits.

CRYSTAL SYMMETRY. It is an obvious characteristic of a crystal that it possesses the property of appearing unchanged after the performance of some simple geometrical operation, such as rotation about an axis, or reflexion in a plane. This **symmetry** (see the various classifications under the term symmetry) is a consequence of the identical property of the underlying crystal **lattice.**

CRYSTAL SYSTEMS. It can be shown by geometry that there exist 32 different classes of crystal symmetry, or point groups. These are conveniently classified into seven (by some authors, six) systems, characterized by their axial angles and ratios. (See table on p. 203; also **crystallography.**)

CRYSTAL, TEMPERATURE-CONTROLLED. A crystal used in an **oscillator** or **filter,** which has its characteristics stabilized by being placed in a constant-temperature oven.

CRYSTAL, THICKNESS-SHEAR. A piezoelectric crystal designed to operate in the thickness-shear mode of motion.

CRYSTAL, TORSIONAL. A piezoelectric crystal designed to oscillate in the torsional mode of motion.

CRYSTAL TRIODE. See **transistor.**

CRYSTAL, TWIN. Two crystals of the same substance having one common face.

CRYSTAL, UNIAXIAL. A doubly-refracting crystal which has but one optic axis. Examples: Iceland spar, quartz, tourmaline.

CRYSTALLINE ANISOTROPY ENERGY. The energy associated with the effect observed in certain ferromagnetic (see **ferromagnetism**) crystals, whereby the magnetization tends to be directed along certain definite **crystallographic axes,** called directions of easy magnetization.

CRYSTALLINE LENS. The lens of the eye with index of refraction of about 1.437 and located behind the aqueous humor and in front of the vitreous humor.

CRYSTALLITE. One of the grains or small crystals making up a polycrystalline material.

CRYSTALLIZATION. Crystals are formed (1) from solution, (2) from a melt, (3) by sublimation.

(1) The formation of crystals from solution, starting with an unsaturated solution, takes place when a solution is evaporated or cooled below the saturation point, except as retarded by supersaturation. Supersaturation is prevented by the addition of seed crystals of the substance. Since, in the case of the majority of soluble substances, solubility increases with increase of temperature, cooling below the saturation point favors the formation of crystals. A case of wide scope and great importance is that of crystal formation by **precipitation** upon mixing two solutions. Actually, this is the same as for substances of greater solubility, since the substance precipi-

Systems	Crystallographic Elements	Essential Symmetry	Number of Point Groups
Cubic, or regular	Three axes at right angles: all equal. $\alpha = \beta = \gamma = 90°$ $a:b:c = 1:1:1$	4 triad axes; 3 diad, or 3 tetrad axes	5
Tetragonal	Three axes at right angles: two equal. $\alpha = \beta = \gamma = 90°$ $a:b:c = 1:1:y$	1 tetrad axis	7
Orthorhombic or Rhombic	Three axes at right angles: unequal $\alpha = \beta = \gamma = 90°$ $a:b:c = x:1:y$	3 diad axes, or 1 diad axis and 2 perpendicular planes intersecting in a diad axis	3
Monoclinic	Three axes, one pair not at right angles: unequal. $\alpha = \gamma = 90°$ $\beta \neq 90°$ $a:b:c = x:1:y$	1 diad axis, or 1 plane	3
Triclinic or Anorthic	Three axes not at right angles: unequal. $\alpha, \beta, \gamma \neq 90°$ $a:b:c = x:1:y$	No axes or planes	2
Hexagonal	Three axes coplanar at 60°: equal. Fourth axis at right angles to other three. $a_1:a_2:a_3:b = 1:1:1:x$	1 hexad axis	7
Rhombohedral or Trigonal	Three axes equally inclined, not at right angles: all equal. $\alpha = \beta = \gamma \neq 90°$ $a:b:c = 1:1:1$	1 triad axes	5

tated is first formed in solution and the excess above the saturation point separates as precipitate. As a rule the crystals are larger and more perfect the slower their growth. Conversely, when small crystals are desired, rapid stirring and quick cooling are practical. The smaller the crystals of a given substance, the purer the material generally is. Small crystals may be increased in size by allowing them to stand in the mother liquor before separation.

(2) The formation of crystals from a melt takes place when the melted substance is cooled sufficiently slowly near and below the fusion point. If the cooling is rapid the fusion may result in the formation of an undercooled liquid of rigidity corresponding to a solid. (See **glass.**)

(3) The formation of crystals by **sublimation** takes place when the vapor of a substance is condensed as a solid without passing through the liquid phase in so doing. This occurs when the temperature of the condenser is below that of the melting point of the substance. (See **vapor pressure; crystal growth.**)

CRYSTALLIZATION, NUCLEI OF. Small solid particles placed in solutions upon which crystals may form. Crystals of the dissolved substance or of other substances which are **isomorphous** with it, grains of dust, etc., may serve as nuclei. Crystalline particles such as nuclei are often referred to as seed crystals.

CRYSTALLOGRAM. The **x-ray diffraction** pattern of a crystal, whence the **crystal structure** may be obtained.

CRYSTALLOGRAPHIC AXES. Usually three, sometimes four, lines meeting at a point which are so chosen as to bear a definite relationship to the characteristic features of the crystallographic **symmetry.** They may, for example, be normal to the plane of symmetry, or parallel to, or coincident with, the edge between principal faces or the axes of symmetry. Although the choice of axes is to some extent arbitrary, some sets produce a simpler representation than others. Whenever possible, the three axes are chosen to be at right angles to each other.

CRYSTALLOGRAPHIC AXIAL RATIOS. The ratios of the crystal intercepts, i.e., the ratios of distances from the origin of the **crystallographic axes** to the points where they are intercepted by the faces of the **unit cell.**

CRYSTALLOGRAPHIC PARAMETERS. The crystal intercepts, which are the distances from the origin of the **crystallographic axes** to the points where they are cut by the faces bounding the **unit cell** of the crystal.

CRYSTALLOGRAPHIC SYSTEMS. See **crystal systems.**

CRYSTALLOGRAPHY. The branch of physical science which deals with the external shapes of crystals and with the geometrical relations between the **atomic planes** within them. If a solid crystal is broken, it is found to have separated along certain cleavage planes into polyhedral fragments, and measurements show that these planes were all originally parallel to one or another of a few standard planes. In most **crystal systems,** each of the more prominent crystal faces belongs to one of three plane-families, intersecting along the **crystal axes** (in hexagonal crystals there are four). It is observed (**Haüy law**) that if the ratio of the intercepts of two crystal planes on one of these axes is a simple fraction, the ratios of the intercepts on the other axes are also simple fractions, and in this way it is established that the intercepts on any one axis must be multiples of a common unit. A given family of planes is then labeled by its **Miller indices** or **Bravais-Miller indices,** the reciprocals of the ratios of its intercepts with each axis, expressed in terms of the common unit for that axis, and reduced to lowest integral terms. Study of the **axial ratios,** indices, and angles shows that all crystals may be classified into seven **crystal systems.** All the above properties are satisfied if a crystal consists of a regular array of atoms, molecules, ions, etc., in a **space lattice,** and this is verified by the **x-ray analysis of crystal structure.**

CRYSTALLOID. (Dispersoid.) A term used by Graham to distinguish the crystalline substances, which are soluble in water and dialyze readily, from colloidal compounds, which dialyze not at all or only very slowly. This distinction now has little fundamental meaning. Moreover, there are some substances, including some proteins, that crystallize but do not dialyze.

CT. An abbreviation usually used in diagrams to indicate the center-tap of a coil-winding.

CUBATURE. The process of finding a numerical value of a definite double integral of a function of two independent variables. (See **numerical integration.**)

CUBIC. See **equation, cubic.**

CUBICAL ANTENNA. See **antenna, cubical.**

CUMULATIVE DOSE (RADIATION). The total dose resulting from repeated exposures to radiation of the same region, or of the whole body.

CUMULATIVE EXCITATION. An excited atom, in the metastable state, may receive a further increment of energy by collision, as with an electron, and thus be raised to a still higher energy state. This process by which an atom is raised by collision from one excited state to higher states is known as cumulative excitation. In fact, it is possible for an atom in the metastable state to receive sufficient energy by this process to be ionized and this process is designated as cumulative ionization.

CUMULATIVE IONIZATION. Discussed under **cumulative excitation.**

CUMULATIVE METHOD. See **physical measurements.**

CUMULIFORM. A general term applied to all clouds having dome-shaped upper surfaces which exhibit protuberances, the bases of such clouds being generally horizontal. Cumuliform clouds are characteristically distinct and separated from one another by clear spaces.

CUMULONIMBUS. The **thunderstorm** cloud. It is tall, billowed, full of contrast from brilliant white to inky black. Most of the cloud is composed of water droplets but the top which penetrates above the freezing level is composed of ice crystals. **False cirrus** often develops at the top of anvil head. Cumulonimbus occur with bases from 500–15,000 feet and tops from 10,000–50,000 feet.

CUMULUS CLOUDS. Billowed heaps with flat bases and tufted tops. They have considerable shadow and often are very dark on the underside. Size and shape vary from flat small balls of cloud-cotton to great towers with valleys and ravines along the sides. The cloud is a low type, but can be found with bases from 500–1000 feet and tops as high as 20,000 feet. It is composed of water droplets and may produce rain if well developed. Flat, fair-weather types are known as *cumulus humilis* and the well-developed variety as *cumulus congestus.*

CURIE. A unit of radioactivity which was originally defined as the amount of emanation (radon) from or in equilibrium with one gram of radium. Because of experimental uncertainties this unit has been redefined by the revised recommendations of the International Commission on Radiological Units (July, 1953) as follows: "The curie is a unit of radioactivity defined as the quantity of any radioactive nuclide in which the number of disintegrations per second is $3\,700 \times 10^{10}$."

CURIE POINT (CURIE TEMPERATURE). Ferromagnetic materials lose their permanent or spontaneous magnetization above a critical temperature (different for different substances). This critical temperature is called the Curie point. Similarly, **ferroelectric** materials lose their spontaneous **polarization** above a critical temperature. For some such materials, this temperature is called the "upper Curie point," for there is also a "lower Curie point," below which the ferroelectric property disappears.

CURIE-WEISS LAW. The transition from ferromagnetic to **paramagnetic** properties, which occurs in iron and other **ferromagnetic** substances at the **Curie point** is accompanied by a change in the relationship of the **magnetic susceptibility** to the temperature. P. Curie stated in 1895 that above this point the susceptibility varies inversely as the absolute temperature. But this was found to be not generally true, and was modified in 1907 by P. Weiss to state that the susceptibility of a paramagnetic substance above the Curie point varies inversely as the excess of the temperature above that point. At or below the Curie point, the Curie-Weiss law does not hold.

CURIUM. Transuranic element. Symbol Cm. Atomic number 96.

CURL. A vector resulting from the action of the operator **del** on a vector, **V**, by **vector multiplication,**

$$\text{curl } \mathbf{V} = \nabla \times \mathbf{V} = \mathbf{i}\left\{\frac{\partial V_z}{\partial y} - \frac{\partial V_y}{\partial z}\right\} + \mathbf{j}\left\{\frac{\partial V_x}{\partial z} - \frac{\partial V_z}{\partial x}\right\} + \mathbf{k}\left\{\frac{\partial V_y}{\partial x} - \frac{\partial V_x}{\partial y}\right\} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ V_x & V_y & V_z \end{vmatrix}$$

The curl is also called the **rotation** (abbreviated rot). (See also **Stokes theorem.**)

CURRENT AMPLIFICATION. (1) Of an **amplifier,** the ratio of the current produced in the output circuit as a result of the current supplied in the input circuit, to the current supplied to the input circuit (2) Of a **magnetic amplifier** control-winding, the ratio of the change in output current to the change in current in the control winding required to produce the output current change. Assuming the change from minimum to maximum output current to be 100%, the nominal current amplification will be measured over the following range: An output current 20% greater than the minimum to an output current 20% less than the maximum Current amplification should be specified for operations of the magnetic amplifier at its rating except for control currents and output currents The current amplification shall be the minimum that exists for any condition within the rating (3) Of a **multiplier phototube,** the ratio of the output current to the **photocathode current** due to photoelectric emission at constant electrode voltages Terms output current and photocathode current as here used do not include **dark current.** This characteristic should be measured at levels of operation that will not cause saturation (4) Of a **transducer,** the ratio of the magnitude of the current in a specified load impedance connected to a transducer to the magnitude of the current in the input circuit of the transducer If the input and/or output current consist of more than one component, such as multifrequency signal or noise, then the particular components used and their weighting must be specified By custom, this amplification is often expressed in **decibels** by multiplying its common logarithm by 20

CURRENT AMPLIFICATION, TRANSISTOR. See **transistor parameter h_{21}.**

CURRENT ATTENUATION. Of a transducer, the ratio of the magnitude of the current in the input circuit of a transducer to the magnitude of the current in a specified load impedance connected to the transducer. If the input and/or output current consist of more than one component, such as multifrequency signal or noise, then the particular components used and their weighting must be specified By custom this attenuation is often expressed in **decibels** by multiplying its common logarithm by 20

CURRENT, AVERAGE. The average value of a current (I) over a time interval (t_1, t_2) is

$$\langle I \rangle = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} I dt$$

CURRENT BALANCE. A system of fixed and movable coils of accurately known dimensions so arranged that the force developed between the coils (by the passage of current) can be balanced by the force of gravity acting on a known mass Such an arrangement is used for the absolute determination of the ampere

CURRENT CIRCUITS, ENERGY OF A SYSTEM OF. See **energy of a system of current circuits.**

CURRENT CONDUCTION. Electric current consisting of the flow of free charges, as distinct from displacement current.

CURRENT DENSITY. (1) A vector representing the time rate of flow of electric charge per unit area The direction of the vector is the direction of positive charge flow; the magnitude is the limit of the flow rate per unit area as the area approaches zero The area considered is perpendicular to the direction of flow (Cf **displacement current density.**) (2) In nuclear physics, a vector such that its component along the normal to a surface equals the net number of particles crossing that surface per unit area and unit time. Commonly referred to simply as current, as in neutron current. (3) By analogy with electric current, a vector representing the time rate of flow of any quantity such as mass or momentum, per unit area in a transport. process.

CURRENT, DIFFUSION. See **diffusion current.**

CURRENT, DIRECT. (1) A current through a specified surface, which does not change sign. (Note that current is a **scalar.**) (2) A steady current.

CURRENT, DISPLACEMENT. Consider a **capacitor** hidden in a "black box" with two terminals. Charging or discharging the capacitor requires a charge flow, or current, in the external connections. Viewed externally, let a current of positive charges flow into one terminal; the equal current of negative charges into the second terminal appears to be a positive current out of the second terminal. It is logically awkward to think of a current into one terminal and out of the other, that doesn't go through the box. Hence, to maintain continuity of current, a "displacement" current is postulated in the capacitor, equal to the "conduction" current in the external connections.

This concept of displacement current was invented by Maxwell to simplify the mathematical equations of **electromagnetism;** it led to the prediction of **electromagnetic waves.**

The displacement current is more than a convenient fiction, as is indicated by the fact that the **Biot-Savant** law holds when the circuit surrounds a displacement current as well as when it surrounds a conduction current. Part of the displacement current can be accounted for as the movement of bound charges within the dielectric, i.e., the creation or reorientation of dipoles. The balance, which is exhibited even in a vacuum, may be better understood as **quantum electrodynamics** is further developed.

Precisely, the displacement current through a surface is defined as the integral of the normal component of displacement current density over that surface. The displacement current density is the time derivative of the **electric induction.**

CURRENT, EDDY. The current which flows in a conductor as a result of flux linkage changes seen by that conductor. It is, in general, an undesirable effect, as opposed to the load current in the secondary of a transformer which is the result of flux linkage changes. Eddy currents contribute to the power losses in magnetic cores, conductive shields, and the conductors themselves.

CURRENT, EFFECTIVE OR ROOT-MEAN-SQUARE. The root-mean-square value of a current (I) over a time interval (t_1, t_2) is

$$\text{Rms } I = \left[\frac{1}{t_2 - t_1}\int_{t_1}^{t_2} I^2 dt\right]^{1/2}.$$

For a sinusoidal current, the rms value over any integral number of periods is $\sqrt{2}/2 = 0.707$ times the peak value. Since the power (e.g., heat in a resistor) depends on the square of the current, the rms value is frequently called the "effective value." The term "effective value" is deprecated in modern usage.

CURRENT, ELECTRIC. Broadly, the flow of electric charge. More specifically, the time rate at which charge crosses a given surface is the current across the surface. There are actually three types of current: conduction current, convection current, and displacement current. Conduction current is due to the motion of charges in a neutral system (as **electrons** in a **conductor,** or the motion of electrons and **"holes,"** which contribute largely to the current in **semiconductors**); convection current is due to the motion of unneutralized charge, as the motion of electrons in a vacuum tube; displacement current is an effect of a changing electric flux. Current is a scalar. The current through a specified surface is given by the integral over that surface of the normal component of **current density.** In loose usage, we often speak of the direction of a current; actually, being a scalar, current has a sense (plus or minus) but not a direction. (See **electric circuits;** the **Ohm law; ampere; electromagnetism;** etc.)

CURRENT FEED. The connection of the feed transmission line to the maximum current point in an antenna system.

CURRENT (OR STREAM) FUNCTION. The stream or current function is a scalar function of position used to describe steady two-dimensional flow of an incompressible fluid. The current function, ψ, is defined by

$$u = \frac{\partial\psi}{\partial y}, \quad v = -\frac{\partial\psi}{\partial x}$$

where u, v are the components of the velocity parallel to Ox, Oy. It will be noticed that the flow across any line from the point A to the point B is

$$\int_A^B (udy - vdx) = \int_A^B \nabla\psi \cdot ds$$
$$= \psi_B - \psi_A.$$

CURRENT GAIN, TRANSISTOR. See **transistor parameter α.**

CURRENT, GATE. The current through the **gate winding of a magnetic amplifier.** This current may be either a-c or pulsating d-c.

CURRENT, IMPRESSED. An electric network may be energized by applying (impressing) either known voltages or known currents on its terminals. For purposes of analysis, it is often convenient to consider given *impressed* currents, with the *resulting* voltages as the unknowns to be solved for.

CURRENT IN CIRCUIT, GROWTH AND DECAY OF. When a step-wave, $V = 0$ for $t < 0$, and $V = V_0$ for $t > 0$, V being the voltage, is applied to an RL (resistance-inductance) or RC (resistance-capacitance) circuit, the current grows (or decays) exponentially with time. In the exponential expression $e^{-\alpha t}$, α^{-1} is called the time constant.

CURRENT, INDUCED. In induction heating usage, current in a conductor due to the application of a time-varying electromagnetic field.

CURRENT, INSTANTANEOUS. The instantaneous value of a **current** which varies with time.

CURRENT, MAGNETIC. See **magnetic current.**

CURRENT, MAGNETIC FIELD OF. See **magnetic field of a current.**

CURRENT-MEASURING REACTOR. Synonym for **d-c transformer.**

CURRENT, POLARIZATION. That component of displacement current (see **current, displacement**) due to the time rate of change of polarization.

CURRENT, PUSH-PULL. See **push-pull current.**

CURRENT SATURATION. See **voltage saturation.**

CURRENT SENSITIVITY. See **sensitivity, current.**

CURRENT SHEET. An infinitely thin sheet carrying finite current per unit length normal to the lines of flow. This current may be either electric or magnetic. (See **magnetic current.**)

CURRENT, SINUSOIDAL. A current whose variation with time is sinusoidal, i.e.,

$$I = A \sin (\omega t + \phi).$$

CURVATURE. A measure of the rate of change of direction of a curve. If τ is the angle made with the OX-axis at a point P on the curve and s is the arc length from some fixed point on the curve to P, the curvature at P is $\kappa = d\tau/ds$. In Cartesian coordinates,

$$\kappa = \frac{d^2y/dx^2}{[1 + (dy/dx)^2]^{3/2}}.$$

The radius of curvature is $\rho = 1/\kappa$.

CURVATURE (GAUSSIAN) OF SPACE-TIME. $G = g^{\mu\nu} G_{\mu\nu}$ where $g^{\mu\nu}$ are the contravariant metric components and $G_{\mu\nu}$ is the **contracted Riemann-Christoffel tensor.** The vanishing of G does not imply that space-time is flat.

CURVATURE OF FIELD. One of the five geometrical aberrations of lenses. If a system is corrected so that there is no spherical aberration, no coma, and no astigmatism, the images of off axis points will lie on a curved surface called the Petzval surface.

CURVATURE OF LENS, TOTAL. The quantity K, defined by the expression

$$K = \frac{1}{r_1} - \frac{1}{r_2}$$

is called the total curvature of a lens. Thus, for a thin lens:

$$\frac{1}{f} = (n - 1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right) = (n - 1)K.$$

CURVATURE OF SURFACE. The curvature of a surface is the reciprocal of the radius of **curvature.**

CURVATURE TENSOR. See **Riemann-Christoffel tensor.**

CURVILINEAR CONE. A **loudspeaker** having an essentially parabolic-shaped cone.

CURVILINEAR MOTION OF A PARTICLE IN A PLANE. The differential equations of motion of a particle of mass m in a plane are (in rectangular coordinates):

$$m\ddot{x} = F_x$$

$$m\ddot{y} = F_y$$

where F_x and F_y are the components of the resultant force acting on the particle. The solutions of these equations give the **parametric equations** for the motion of the particle. The motion of a projectile, the motion of the planets around the sun and the composition of two perpendicular **simple harmonic motions** are examples of this type of motion.

CUSP. A **singular point** on a curve where there are two coincident tangents. If there is a **branch** of the curve on each side of the double tangent, the cusp is of the first kind (e g , the semicubical **parabola**); if the two branches lie on the same side of the double tangent, the cusp is of the second kind If the curve is represented by $f(x,y) = 0$, the condition for a cusp, and also for a **point of osculation**, is

$$\left(\frac{\partial^2 f}{\partial x \partial y}\right)^2 - \frac{\partial^2 f}{\partial x^2}\frac{\partial^2 f}{\partial y^2} = 0.$$

CUTOFF. (1) A particular point in a cycle, or magnitude of a quantity, at which a mechanism, electric circuit, or other system, cuts off some flow to or from it. Thus, the steam engine cutoff is that percentage of stroke accomplished by the piston, when the inlet valve closes and prevents more steam entering the cycle from the boiler. The cutoff of a Diesel cycle is the fraction of the stroke accomplished when supply of fuel oil to the cylinder is stopped. In electronic usage, the word cutoff often appears as a contraction for **cutoff frequency.** (2) A technique used in theoretical physics when the theoretical contribution to the value of a physical quantity arising from integration over part of the range of a certain parameter is not to be believed, in particular when such a contribution is infinite. The integral is cut off, usually at some high frequency limit, with the acknowledgment that beyond this limit either the method of approximation, or the theory itself, will have to be modified in the future.

CUTOFF BIAS. This is the voltage which must be applied to the **grid** in order to stop the flow of anode or plate current in a vacuum **tube.** It is a valuable reference point in the discussion of vacuum tube characteristics as much of the tube behavior is determined by where the bias voltage is set with respect to the cutoff value. (See **cutoff, voltage.**)

CUTOFF FREQUENCY (CUTOFF). (1) Of a **transducer,** either a theoretical cutoff frequency or an effective cutoff frequency (see **cutoff frequency, effective** and **cutoff frequency, theoretical**). (2) Of a **wave filter,** the frequency at which the **attenuation** begins to increase sharply. In the ideal filter, the attenuation would go to infinity at the cutoff frequency, but in a practical filter the rise in attenuation is not so abrupt, and never reaches infinity, but does usually go to a very high value (3) For a given transmission mode in a non-dissipative, **uniconductor waveguide,** the frequency below which the **propagation constant** is real.

CUTOFF FREQUENCY, ABSOLUTE. The lowest frequency at which a (lossless) **waveguide** will propagate energy without **attenuation.**

CUTOFF FREQUENCY, EFFECTIVE (EFFECTIVE CUTOFF). A frequency at which the insertion loss of a **transducer** between specified terminating impedances exceeds by some specified amount the loss at some reference point in the transmission band.

CUTOFF FREQUENCY, THEORETICAL (THEORETICAL CUTOFF). A frequency at which, disregarding the effects of dissipation, the **image attenuation constant** of a **transducer** changes from zero to a positive value, or *vice versa.*

CUTOFF, VOLTAGE. Of an electron tube, that electrode voltage which reduces the value of the dependent variable of an electron-tube characteristic to a specified low value. A specific cutoff characteristic should be identified as follows: current versus grid cutoff voltage, spot brightness versus grid cutoff voltage, etc.

CUTOFF, WAVELENGTH. Of a uniconductor **waveguide,** the ratio of the velocity of **electromagnetic waves** in free space to the **cutoff frequency.**

CUT PARABOLOIDAL REFLECTOR. See **reflector, cut paraboloidal.**

CUT-SET. A set of branches of a **network** such that the cutting of all the branches of the set increases the number of separate parts of the network, but the cutting of all the branches except one does not.

CUTTER (CUTTING HEAD). An electromechanical transducer (see **transducer, electromechanical**) which transforms an electric input into a mechanical output, typified by mechanical motions which may be inscribed into a recording medium by a cutting stylus.

CUTTING ANGLE. The angle between the vertical cutting face of a cutting stylus and the record surface. Ideally, 90°; deviations are called **dig-in angle** or **drag angle.**

CUTTING HEAD. See **cutter.**

CUTTING STYLUS. The cutting tool in the **cutter.** It may be an appropriately-shaped piece of diamond, sapphire, or steel.

CYBOTACTIC GROUPS. A term introduced by Stewart in connection with the structure of liquids, particularly those liquids containing long-chain molecules. A microcrystalline structure is assumed in which the groups consist of molecules which are arranged side-by-side, or end-to-end, in an orderly manner. These groups are considered to be in dynamic equilibrium with the molecules which have random orientation.

CYBOTAXIS. The three-dimensional arrangement of molecules of a substance; in general, the term is applied to liquid, noncrystalline substances. Two of the most common arrangements are the end-to-end (AB··· BA) and the side-by-side $\left(\begin{array}{c}AB\\ \vdots\\ AB\end{array}\right)$ forms, with **coordinate bonds,** such as exist between certain contiguous atoms or radicals, as indicated by the dotted lines.

CYCLE. (1) The complete sequence of values of a periodic quantity which occur during a period. (2) A series of changes executed in orderly sequence, by means of which a mechanism, a working substance or a system is caused periodically to return to the same initial condition, constitutes a cycle. Many complicated machines or assemblages of machines work in definite cycles. An important form of cycle is the heat-engine cycle, in which a series of thermodynamic changes in a working medium periodically return the system to the same thermodynamic level. (See **Otto cycle, Carnot cycle, Rankine cycle, regenerative cycle,** etc.)

CYCLIC SHIFT. In computer terminology, an operation which produces a word whose characters are obtained by a cyclic permutation of the characters of a given word.

CYCLING. A periodic change of the **controlled variable** in an **automatic controller.**

CYCLOID. The path described by a point on a circle as it rolls along a straight line and a special case of a **trochoid.** If the radius of the circle is a, there are **cusps** in the curve, separated by the distance $2\pi a$, every time the point touches the line. (See also **brachistochrone.**)

CYCLONE. A wind system around low atmospheric pressure. If a barometric depression is sufficiently low to be classed as a cyclone, it develops or has associated with it winds which flow around its center counterclockwise in the northern hemisphere and clockwise in the southern hemisphere. The intensity of a cyclone depends on the **pressure gradient** between the system's center and periphery, and on the characteristics of the air masses involved. Cyclones are divided into two groups.

(1) Tropical cyclones are vortices with indefinite or short-lived frontal structures which occur over the tropical and subtropical regions, particularly over the western half of the Atlantic and Pacific and over the Indian Ocean. They are known as hurricanes, typhoons, and baguios.

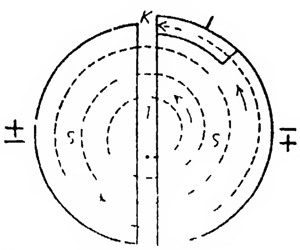
(2) Extra-tropical or wave cyclones are composed during development, youth and maturity of definite parts including warm and cold sectors and warm and cold fronts, but beyond maturity approach vortex structure. Nearly all the storms of the temperate zone are wave cyclones.

CYCLOPHON. A name given to a generic type of **vacuum tube** utilizing a beam of electrons as a switching or commutating element.

CYCLOSTROPHIC WIND. Winds which blow as a result of a pressure **gradient** and centrifugal force, but in the absence of **Cori-**

olis force. They are, of necessity, cyclonic and restricted to equatorial zones which is the only place Coriolis force is zero, or nearly zero. The cyclostrophic component of a wind is the difference between the **gradient** and the **geostrophic winds.** Hurricanes are largely cyclostrophic winds until they travel north or south sufficiently to be affected by Coriolis force.

CYCLOTRON. The magnetic resonance accelerator, a device developed in 1931 by Lawrence and Livingston for imparting very great velocities to heavier **nuclear particles** without the necessity of excessive voltages. The electrified particles (such as protons or helium nuclei) are released in the region between two large, flat, hollow, semicircular segments of thin metal placed with their diametric edges closely parallel, as if one had cut a pill-box in two along a diameter and slightly separated the halves. (See figure.) These segments,



Diagrammatic plan of cyclotron. Ions released in interspace I, traverse hollow sectors S in semicircles, and are finally utilized or allowed to escape at K.

called "dees," are given a high-frequency alternating potential difference, producing a rapidly oscillating field in the space between them, and thus causing a free particle to be pulled first one way and then the other. A strong, uniform magnetic field is applied perpendicular to the plane of the segments. The result is that, as a particle darts into one of the segments, it follows a semicircular path of radius proportional to the speed (as in a **mass spectrograph**) and re-enters the interspace on the other side of the center. The time required for this semicircular journey depends only upon the intensity of the magnetic field, and does not change with the velocity of the particle and the radius of its path. Now if the field is adjusted so that this time equals ½ the electric oscillation period, the particle will always emerge into an electric field so directed as to pull it in the direction it is already going, and in this way its speed increases at each crossing of the interspace. Thus, starting near the center, the particle spirals outward and speed increasing each half-turn, until it finally escapes into a receptacle K near the outer edge. The apparatus must, of course, be in a vacuum.

CYCLOTRON FREQUENCY. The frequency at which an electron traverses an orbit in a steady, uniform magnetic field and zero electric field. It is given by the product of the **electronic charge** and the **magnetic flux density,** divided by 2π times the **electron mass.**

CYCLOTRON - FREQUENCY MAGNETRON OSCILLATIONS. Those oscillations whose frequency is substantially the **cyclotron frequency.**

CYLINDER. A solid bounded by a **cylindrical surface** and two parallel planes. The terms cylinder and cylindrical surface are often used interchangeably but the former is strictly a solid and the latter a surface.

CYLINDRICAL COORDINATES. A **curvilinear** system of right-circular **cylindrical surfaces** forming families of circles about the origin in the XY-plane of a rectangular Cartesian system (ρ = const.); half-planes from the Z-axis (ϕ = const.); planes parallel to the XY-plane (z = const.). The position of a point in this system is given by (ρ, ϕ, z) where

$$x = \rho \cos \phi; \quad y = \rho \sin \phi; \quad z = z.$$

More precisely the system should be called circular cylindrical because **elliptical** and **parabolic** cylindrical coordinates are also used.

CYLINDRICAL LENS. See **lens, cylindrical.**

CYLINDRICAL REFLECTOR. See **reflector, cylindrical.**

CYLINDRICAL SURFACE. Frequently called a **cylinder,** it is a limiting case of a **quadric surface** where only two variables are needed in the equation which describes it. The surface may be generated by a line parallel to a fixed direction, called the **axis,** which

moves along a fixed curve. If the axis is chosen as the Z-axis, its equation is

$$Ax^2 + 2Hxy + By^2 + 2Gx + 2Fy + C = 0$$

Special cases for the surfaces, together with their names, are: (1) $ax^2 + by^2 = 1$, elliptic; (2) $ax^2 - by^2 = 1$, hyperbolic; (3) $y^2 = cx$, parabolic. If $a = b$ in case (1), the result is a right-circular cylindrical surface. The names are derived from the generating curves.

CYLINDRICAL WAVE. See **wave, cylindrical.**

D

D. (1) Mass per unit volume or density (D, but ρ is preferred). (2) Density of electric flux (**D**). (3) Optical density or absorbance (D). (4) Diameter (d or D). (5) Dielectric flux density (**D**). (6) Coefficient of fluid diffusion (D). (7) Dioptric power (**D**). (8) Angular dispersion (D). (9) Electric displacement (**D**). (10) Displacement flux density (**D**) (11) Deuterium (D). (12) Dextrorotatory (d- or d-). (13) Differential (followed by another letter or letters) (d). (14) Spacing of Bragg planes in a crystal (d) (15) Grating space (d) (16) Distance between lens units in an optical system (d) (17) Angle of minimum deviation (D). (18) Optical attenuation (D). (19) In spectroscopy, unresolved doublet (d) (20) Type of electron with an azimuthal quantum number of 2 (d). (21) Spectral term symbol for L-value of 2 (D). (22) The differential operator d/dx (D)

D-CENTER. See **color center.**

D-LINE. Fraunhofer lines at 5889.95 and 5895.92 A caused by sodium in the atmosphere of the sun. Hence the yellow sodium spectrum lines at these wavelengths

D REGION. The region of the **ionosphere** up to about 90 kilometers above the earth's surface.

DAHL-KIRKAM TELESCOPE. In the customary **Cassegrainian telescope** the collecting mirror is parabolic and the secondary mirror hyperbolic, thus involving two aspheric surfaces. In the Dahl-Kirkam telescope, the secondary mirror is spherical and the collecting mirror is given the necessary further correction to eliminate spherical aberration.

D'ALEMBERT PRINCIPLE. The principle, first pointed out by d'Alembert in 1742, that the **Newton third law** holds for forces acting upon bodies entirely free to move as well as upon fixed bodies in stationary equilibrium. The principle is most valuable in dealing with a system of particles subject to constraints. It then says that if the n particles are acted on by a system of impressed external forces $F_1, F_2, \cdots F_n$, the effective force in the jth particle,

$$m_j \cdot \dot{\mathbf{v}}_j = m_j \cdot \ddot{\mathbf{r}}_j$$

is obtained by expressing the condition that the system is in equilibrium under the action of the forces $\mathbf{F}_j = m_j\ddot{\mathbf{r}}_j$, which may indeed be labeled the constraint forces.

D'ALEMBERT TEST. See **Cauchy convergence test.**

D'ALEMBERTIAN. The differential operator

$$\Box^2 = \left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\right).$$

It represents a four-dimensional **contracted covariant** derivative of second order For any scalar ϕ, $\Box^2\phi$ is a **Lorentz invariant** and $\Box^2\phi = 0$ is the **wave equation** for waves traveling with the velocity of light. In **Minkowski space** the d'Alembertian may be written as an obvious Lorentz covariant operator

$$\Box^2 = \frac{\partial}{\partial x_\mu}\frac{\partial}{\partial x_\mu}.$$

DALTON LAW. If several gases not reacting chemically upon each other are introduced into the same container, the pressure of the resulting mixture is equal to the sum of the pressures which would be observed if each gas were separately enclosed in that container. Like other gas laws, this law is approximately valid only within limits. It holds universally for ideal gases.

DAMPED WAVES. See **waves, damped.**

DAMPING. This term usually refers to the checking of a motion due to resistance, as by friction or similar cause. It is of especial significance in connection with the diminishing amplitude of an **oscillation,** as that of a pendulum swinging in the air, or that of the electricity vibrating in an oscillating circuit.

Unless energy is supplied during each cycle, the amplitude of such a vibrator falls off at each successive oscillation by an amount commonly expressed in terms of the decrement, or damping factor, which is the ratio of any one amplitude to that next succeeding it in the same sense or direction.

In so-called logarithmic damping, this decrement is constant; in a simple oscillating electric unit, the amplitude decays as $e^{\delta t}$, where t is the time and δ, the logarithmic decrement, is a constant depending upon the effective resistance, inductance, and capacitance of the circuit. (See **electric oscillations and waves.**) An important instance of damping is found in the reading of an oscillating index, like a balance pointer, on a scale. If one may assume that the amplitude falls off by equal amounts at each swing ("linear" damping), in order to find the equilibrium position, one has only to average an even number of readings at one extreme and an odd number at the other, and then find the mean of the two averages. This linear damping assumption is an approximation to the relationship $e^{\delta t} = 1 - \delta t$ for small damping. (See **time-constant.**)

DAMPING, CRITICAL. That value of **damping** which gives the most rapid transient response which is possible without overshoot. In a system in which the variable x obeys the differential equation

$$a\frac{d^2x}{dt^2} + b\frac{dx}{dt} + cx = 0$$

the condition for critical damping is that

$$b = 2\sqrt{ac}$$

DAMPING FACTOR. Defined in entry on **damping.**

DAMPING, LINEAR. Defined in entry on **damping.**

DAMPING, LOGARITHMIC. Defined in entry on **damping.**

DAMPING, OPTIMAL. That value of **damping,** with the **damping ratio** slightly less than unity, at which an indicating system such as a galvanometer will overshoot its final deflection by less than the desired **uncertainty** in reading the instrument. In general, optional damping results in faster readings than does critical damping, with no real loss in accuracy.

DAMPING RATIO. The ratio of the actual **damping** to the **critical damping.**

DAMPING TUBE. In electromagnetic-deflection, **cathode-ray tubes,** a tube used with magnetic deflecting-coils to prevent any transient oscillations from being set up in the tube or its associated circuits.

DANGER COEFFICIENT. The danger coefficient of a substance for a particular nuclear **reactor** is the change in reactivity caused by inserting that substance in the reactor. The danger coefficient depends on the amount and distribution of the substance inserted and is usually quoted as reactivity change per unit mass for a standard position in the reactor.

DARAF. The unit of **elastance** or reciprocal of capacitance.

DARK ADAPTATION. The sensitivity of the eye gradually decreases as the eye is exposed to increasing brightness. Eyes exposed to no light or to only faint red light become more sensitive as they become more "dark adapted."

DARK CONDUCTION. The flow of **electrode dark current.**

DARK CURRENT. A current that flows in photoemissive and photoconductive detectors (see **detectors, infrared**) when there is no radiant flux incident upon the electrodes (total darkness). The dark current may vary considerably with temperature.

DARK DISCHARGE. An electrical discharge in a gas without the production of visible light.

DARK FIELD ILLUMINATION. For observing very small particles or very fine lines with a microscope, a condenser is used which sends the light through the object at such angles that it does not pass by transmission into the objective. Small particles or lines serve to diffract the light so that a small particle appears as a bright star against a dark background.

DARK SPACE, FARADAY. See **Faraday dark space.**

DARK SPOT. A spot sometimes seen in a television image, due to an electron-cloud

formation in front of a portion of the mosaic of a television camera tube. This condition is corrected at the studio by the use of **shading signals.**

D'ARSONVAL GALVANOMETER. See **galvanometer, d'Arsonval.**

DASYMETER. (1) An instrument used to determine the density of a gas. It consists of a thin glass globe which is weighed in the (unknown) gas or mixture of gases and then in a gas of known density.

(2) An instrument used to determine the composition of flue gas.

DAUGHTER ELEMENT. See **decay product.**

DAVISSON CHART. A chart relating thermionic-emission current density in terms of cathode power dissipation. The coordinates are skewed in a manner which causes the log of current density as a function of the log of power to be a straight line.

DAVISSON-GERMER EXPERIMENT. In 1927, Davisson and Germer demonstrated the wave nature of electrons by directing electron beams at crystals; in particular at a crystal of nickel cut parallel to the (III) planes, and upon varying the electron speed at a fixed angle of incidence, they found not only a distinct "regular" reflection but also a series of diffraction maxima strikingly similar to those obtained with the same crystal for x-rays of varying wavelength. The differences observed were satisfactorily explained as due to the refraction of the nickel for the electron waves. This experiment confirmed the de Broglie hypothesis of the wave nature of material particles, and so prepared the way for wave-particle duality, and for the further development of **wave-mechanics.** It was performed independently by G. P. Thomson

DAVY EXPERIMENT. An experiment carried out by Humphrey Davy in 1799 which showed that two pieces of ice or other substance with a low melting-point could be melted by rubbing them together, without any other addition of heat. The experiment helped to disprove the caloric theory of heat.

DAY, MEAN SOLAR. The average time between successive transits of the sun across the meridian at any given point on the earth's surface. The mean solar day forms the basis of all terrestrial time measurements.

DAY SYSTEM. A bandwidth-conservation system which uses two quadrature carriers individually amplitude-modulated by separate and different modulating waves The two modulated waves are added and applied to the transmitting medium. At the receiver, the transmitted wave is applied to a pair of product demodulators Each **demodulator** is supplied with a **carrier** in phase with the corresponding component of the received carrier. The spectrum occupied is the same at it would have been for a single carrier.

DAYLIGHT FACTOR. The ratio of the daylight illumination at any point in a building to the simultaneous illumination under the open sky.

DB. Abbreviation for **decibel.**

DBM. A symbol for **power level** in **decibels** with reference to a power of one milliwatt (0.001 watt)

D-C. See **direct current.**

D-C/A-C CONVERTER, MAGNETIC. See **magnetic modulator.**

D-C BRAKING. See **braking, dynamic.**

D-C INSERTION. The **clamping** of the video signal at the pedestal level in a television transmitter, thus effectively inserting a d-c component in the signal This action allows a **d-c restorer** to determine the correct signal brightness level at the receiver

D-C MAGNETIC BIASING. See **magnetic biasing, d-c.**

D-C PICTURE TRANSMISSION. The transmission of a television signal with the d-c component represented in the **picture signal.**

D-C RESTORER. A device which clamps either the positive or negative peak value of a **waveform** to some desired level. In television receivers the waveform is clamped at the **pedestal level,** thus effectively restoring the black level established at the studio. (See **d-c insertion; clamper.**)

DEACCENTUATOR. A **network** used in **frequency-modulation** reception to achieve **de-emphasis.**

DEAD BAND. (1) In general, the range of values through which the measured variable which is the input to the **automatic controller** can be varied without initiating effective response. (2) In a **magnetic amplifier,** a region of input signal change which causes no change in the output.

DEAD ROOM. A room which is characterized by an unusually large amount of sound absorption.

DEAD SPOT. (1) A location in which radio reception over some band of frequencies is weak or non-existent. (2) A spot on a receiver dial which has poor or no **sensitivity,** due to improper receiver design.

DEAD TIME. See **counter dead time.**

DEAD TIME CORRECTION. Correction to the observed counting rate to allow for the probability of the occurrence of events within the **counter dead time.**

DEAD TIME LAG. See **transportation delay.**

DE BROGLIE WAVELENGTH. A wavelength ascribed to any particle having momentum. For a relativistic particle, the value of this wavelength is given by the expression:

$$\lambda = \frac{h}{mv} = \frac{h}{m_0 v}\sqrt{1 - \frac{v^2}{c^2}}$$

where λ is the de Broglie wavelength, h is the Planck constant, m_0 is the rest mass of the particle, v is its velocity and c is the velocity of light. The observed mass of the particle is m and the **momentum** is mv.

DEBUNCHING. The action of forces of mutual repulsion between electrons causing the **bunches** of electrons to spread, both laterally and longitudinally.

DEBYE DIPOLE THEORY. A theory describing the specific inductive capacity of a liquid composed of molecules with a permanent dipole moment. If the influence of one dipole on another is only to modify the mean field, the theory leads to the Lorentz formula,

$$\frac{\epsilon - 1}{\epsilon + 2} = \frac{4\pi}{9}\frac{\mu^2 n}{kT}$$

where ϵ is the specific inductive capacity, μ is the strength of a single dipole, n is the number density. For liquids such as water, the degree of mutual orientation of dipoles in each others fields is so great that an allowance for this effect is necessary.

DEBYE EQUATION FOR TOTAL POLARIZATION. A relationship giving the total **polarization** P_M of an assembly of N molecules of **polarizability** α and **dipole moment** μ, at absolute temperature T, in the form:

$$P_M = \frac{4\pi}{3} N\left(\alpha + \frac{\mu^2}{3kT}\right).$$

This equation is used with the **Clausius Mosotti relation** and the **dielectric constant** to obtain the **dipole moment.**

DEBYE EQUATION OF STATE. The relation between pressure p, and volume V,

$$p = \frac{\partial U_0}{\partial V} + \gamma\frac{U_D}{V}$$

where γ is **Grüneisen's constant,** U_0 is the **internal energy** at 0°K, and U_D is the contribution to the internal energy due to the lattice vibrations.

DEBYE-FALKENHAGEN EFFECT. The variation of the **conductance** of an electrolytic solution with **frequency.** This effect, which is noted at high frequencies, is also called the dispersion of conductance.

DEBYE FREQUENCY. The frequency defining the **Debye temperature.**

DEBYE HEAT CAPACITY EQUATION. The **Debye theory of specific heat** gives the **molar heat capacity** of a solid as a function of its **Debye temperature** Θ, in a relationship of the form:

$$C_V = 3NkF_D(\Theta/T)$$

where

$$F_D(x) = 3x^{-3}\int_0^x \frac{e^y y^4 dy}{(e^y - 1)^2}$$

(the Debye function). At high temperatures, this gives the **Dulong and Petit Law,** $C_v \rightarrow 3Nk$. At low temperatures, $C_V \propto T^3$, the **Debye T^3 Approximation.** (N is the number of atoms per mole, k is the **Boltzmann constant.**)

DEBYE-HÜCKEL EQUATION, COMPLETE. The Debye-Hückel equation (which is stated in the entry for **Debye-Hückel lim-**

iting law) corrected for finite size of the ions, and the attraction between the ions and the dipolar molecules of the solvent.

DEBYE-HÜCKEL LIMITING LAW. The departure from ideal behavior in a given solvent is governed by the **ionic strength** of the medium and the valences of the ions of the electrolyte, but is independent of their chemical nature. For dilute solutions, the logarithm of the **mean activity** is proportional to the product of the cation valence, anion valence, and square root of **ionic strength** giving the equation $-\log f_{\pm} = Az_{+}z_{-}\sqrt{\mu}$. (See **theory of electrolytes.**)

DEBYE-HÜCKEL, THEORY OF CONDUCTIVITY OF ELECTROLYTES. See **theory of electrolytes.**

DEBYE-SCHERRER-HULL METHOD. A technique of **x-ray diffraction,** in which a beam of x-rays is directed on a powdered sample of the material (hence the name "powder method") and the diffracted beams received on a photographic plate. Because the powder contains crystals in every orientation, the plate shows a pattern of concentric rings, which is characteristic of the material and may be used to identify it, or to obtain very accurate estimates of the cell dimensions.

DEBYE-SEARS CELL. A device for measuring velocity and attenuation of compressional waves in a transparent liquid. (See **Debye-Sears effect.**)

DEBYE-SEARS EFFECT. A piezoelectric crystal vibrating in a longitudinal mode in a liquid sets up acoustic waves consisting of regions of compression and regions of rarefaction in the liquid, which alternate at distances of half a wavelength. Hence, if a parallel beam of light shines through such a crystal tank with plate-glass walls, the regions of density and rarefaction act like a plane light diffraction-grating. If the parallel beam from the cell is focused on a single spot when no sound waves are present, first and higher order diffraction-spectra will appear on either side of the zero-order spot when sound waves are present. From the spacings of the diffraction orders, the sound wavelength can be determined, which, together with the frequency, gives the velocity of sound in the liquid.

DEBYE T^3 APPROXIMATION. According to the **Debye theory of specific heat,** the specific heat of a solid should always tend to proportionality to the cube of the absolute temperature at low temperatures.

DEBYE TEMPERATURE. A parameter having the dimensions of temperature appearing in the **Debye theory of specific heat.** It is defined by the relation

$$\Theta = \frac{h\nu}{k}$$

where ν is the maximum frequency of the *thermal vibrations* of the lattice, h is *Planck's constant* and k is the *Boltzmann constant.* The symbol Θ is also used somewhat indiscriminately in various other contexts (e.g., *electrical conductivity* of metals) where it really should be defined rather differently, and may have a rather different value.

DEBYE THEORY OF SPECIFIC HEAT. The specific heat of solids is attributed to the excitation of **thermal vibrations** of the lattice, whose spectrum is taken to be similar to that of an elastic continuum, except that it is cut off at a maximum frequency in such a way that the total number of vibrational modes is equal to the total number of **degrees of freedom** of the lattice.

DEBYE UNIT. A unit equal to 10^{-18} electrostatic unit of dipole moment.

DECALESCENCE. Absorption of heat, usually by an alloy without rise of temperature, due to an **allotropic transformation.**

DECAY BY NEUTRON EMISSION. See **neutrons, delayed.**

DECAY CHAIN. See **radioactive series.**

DECAY CHARACTERISTIC. See **persistence characteristic.**

DECAY COEFFICIENT. A synonym for **disintegration constant.**

DECAY CURVE. Any **activity curve** in which the **activity** decreases with increasing time.

DECAY ELECTRONS, COSMIC RAY. See **cosmic ray decay electrons.**

DECAY FAMILY. See **radioactive series.**

DECAY LAW, RADIOACTIVE. The exponential law

$$N = N_0 e^{-\lambda t}$$

which governs the decrease with time of the number of atoms of a radioactive species, provided the number is large. In the above equation, N is the number of atoms present at time t, N_0 is the number of atoms present at time zero and λ is the decay constant. The decay law is a statistical law so that if N is the number of radioactive atoms present, the number of which will disintegrate on the average in unit time is λN. The number which will disintegrate in any particular unit of time may not be exactly λN, but if a large number of measurements of the number of disintegrations per unit time is made, the values will show a **Poisson distribution** with λN as the average value.

DECAY MODULUS. In a damped harmonic oscillator, the time for the amplitude of oscillation to diminish to $1/e$ of its initial value is called the decay modulus. For an oscillator with the equation of motion

$$m\ddot{x} + R\dot{x} + fx = 0$$

the decay modulus is $2m/R$. (See **oscillation, damped.**)

DECAY OF SOUND IN A ROOM, EQUATION FOR. See **Franklin equation.**

DECAY PRODUCT. Any **nuclide**, radioactive or stable, resulting from the **radioactive** disintegration of a **radionuclide**, directly or as a result of successive transformations in a **radioactive series.**

DECAY, RADIOACTIVE. (1) Radioactive disintegration (see **radioactivity**). (2) The decrease with time of the number of radioactive atoms in a sample, because of their spontaneous transformation.

DECAY SERIES. See **radioactive series.**

DECELERATION. Negative **acceleration.**

DECI-. This prefix, used before the name of a unit, may be read as one-tenth.

DECIBEL (DB). The decibel is one-tenth of a **bel.** The abbreviation "db" is commonly used for the term decibel. With P_1 and P_2 designating two amounts of power and n the number of decibels corresponding to their ratio

$$n = 10 \log_{10} (P_1/P_2).$$

When the conditions are such that scalar ratios of currents or of voltages (or analogous quantities in other fields such as pressures, amplitudes, particle velocities in sound) are the square roots of the corresponding power ratios, the number of decibels by which the corresponding powers differ is expressed by the following formulae:

$$n = 20 \log_{10} (I_1/I_2)$$

$$n = 20 \log_{10} (V_1/V_2)$$

where I_1/I_2 and V_1/V_2 are the given current and voltage ratios, respectively. By extension, these relations between numbers of decibels and scalar ratios of currents or voltages are sometimes applied where these ratios are not the square roots of the corresponding power ratios; to avoid confusion, such usage should be accompanied by a specific statement of this application.

DECIGRAM. One-tenth **gram.**

DECILITER. One-tenth **liter.**

DECIMAL NUMBER SYSTEM. The method of positional **notation** using ten as the **radix.**

DECIMAL POINT. The **radix point** in the **decimal number system.**

DECIMETER. One-tenth **meter.**

DECIMETRIC WAVES. Waves having wavelengths between 1 and 0.1 meter.

DECINEPER. One-tenth of a **neper.**

DECODER. A device for the detection and interpretation of a pulse-code modulated (see **modulation, pulse-code**) signal.

DECOMPOSITION, SENSITIZED. A chemical decomposition that is brought about by the presence of a second substance which absorbs an **exciting radiation.** The essential mechanism of the reaction is the excitation of particles of the second substance by the radiation, followed by collisions between these excited particles and molecules to be decomposed. The process proceeds most effectively if the energy difference between the **ground state** and excited state of the sensitizer is nearly equal to the energy of the decomposition reaction.

DECOMPOSITION VOLTAGE. The minimum **electromotive force** which must be applied to a given solution and given electrodes to produce steady **electrolysis.** The value of the decomposition voltage is not known precisely because the rise in the current-voltage curve does not begin at a sharply defined point. Instead the curve at first rises very slowly with increasing applied voltage, in the neighborhood of the decomposition voltage there is an abrupt change in slope (a sharp bend) and thereafter the curve rises rapidly with applied electromotive force.

DECREPITATION. The emission of a crackling sound, commonly by **crystals** on shattering under the internal stresses resulting from heating.

DE-EMPHASIS (POST-EMPHASIS) (POST-EQUALIZATION). A form of equalization complementary to **pre-emphasis.**

DE-EMPHASIS NETWORK. See **network, de-emphasis.**

DEFECT. A term used to include various types of point **imperfections** in solids, such as **vacancies, interstitial atoms,** etc., as distinct from extended imperfections such as **dislocations.** Lattice defects are particularly important in ionic crystals where they may be created by heating in the vapor of one constituent, thus creating a stoichiometric excess, by bombardment with **x-rays** and energetic particles, etc. Any crystal must contain a certain equilibrium concentration of defects, as a function of the temperature purely as a result of thermal agitation (see **Frenkel defect, Schottky defect**). Defects are responsible for the **diffusion** of ions, **ionic conductivity,** and the complex phenomena related to **color centers.**

DEFECT CONDUCTION. Conduction by **holes** in the **valence band** of a **semiconductor.**

DEFINITE. Non-zero. A positive definite **form** is always greater than zero. A positive indefinite form is equal to or greater than zero. (See **kernel.**)

DEFINITION CIRCLE. In **impedance matching,** a circle of constant standing-wave ratio surrounding a desired impedance on a complex impedance plane.

DEFLECTING ELECTRODE. See **electrode, deflecting.**

DEFLECTION FACTOR (OF A CATHODE-RAY TUBE). The reciprocal of the **deflection sensitivity.**

DEFLECTION OF LIGHT. See **bending of light.**

DEFLECTION POLARITY OF OSCILLOSCOPE. See **oscilloscope, deflection polarity of.**

DEFLECTION SENSITIVITY. (1) Of an electrostatic-deflection, **cathode-ray tube,** the quotient of the spot displacement by the change in deflecting potential. (2) Of a magnetic deflection **cathode-ray tube,** the quotient of the spot displacement by the change in deflecting magnetic field. (3) Of a magnetic-deflection cathode-ray tube and yolk assembly, the quotient of the spot displacement by the change in deflecting-coil current. Deflection sensitivity is usually expressed in millimeters per volt applied between the deflecting electrodes or in millimeters per gauss of the deflecting magnetic field.

DEFLECTION YOKE. An assembly of one or more coils whose magnetic field deflects an electron beam.

DEFORMABLE BODY. A material body that undergoes changes in size and shape under the influence of external stresses. (See **deformation.**) Distinct from a **rigid body.**

DEFORMATION. The change in the shape or size of a body which accompanies a stressed condition is called deformation or strain. The total amount of change in any one direction is the total deformation in that direction. Unit deformation is the deformation per unit of length. Permanent deformation is known as set. If an axial load is applied to a body, the length and lateral (cross-sectional) dimensions are changed. **Poisson's** ratio is the ratio of lateral unit deformation to longitudinal unit deformation.

Deformation which is the result of a flexural stress (see **flexure**) is called bending deformation. Shearing or shear deformation is caused by **shearing stress.**

DEFORMATION BANDS. Regions within a metal crystal which have assumed different orientations as a result of **slip.**

DEFORMATION POTENTIALS. The effective electric potential acting on a free electron in a **metal** or **semiconductor** as a result

of a local deformation of the crystal lattice. The scattering of electrons by **lattice vibrations** may be analyzed in terms of the deformations produced by the vibrations, and hence the corresponding potentials.

DEGASIFICATION. Removal of gas, as applied particularly to the removal of the last traces of gas from wires used in vacuum tubes, from metals to be plated, and from substances to be used in other specialized applications.

DEGASSING OF GLASS. Glass always contains water, carbon dioxide, oxygen, and traces of other gases within it and on its surface, and these are ordinarily in a state of equilibrium with the surroundings. When the pressure is reduced, however, the equilibrium is upset, and these gases, being gradually released from solution in and adsorption on the glass, spoil the vacuum. It is usual to drive the gases out of the glass by baking the glass at a temperature of about 350°–500°C, while on the pump.

DEGASSING OF METAL. Degassing of metal is necessary for the same reason as in **degassing of glass,** but because of the larger quantities of gas present in metals, more complex methods of degassing must be employed. These include baking at high temperature, eddy-current heating, electron bombardment, etc.

DEGENERACY. See **degenerate state.**

DEGENERACY, ACCIDENTAL. See **Fermi resonance.**

DEGENERACY, COULOMB. See **Coulomb degeneracy.**

DEGENERACY, EXCHANGE. See **exchange degeneracy.**

DEGENERATE ELECTRON GAS. An **electron gas** which is far below its **Fermi temperature,** that is, which must be described by the **Fermi distribution.** The essential characteristic of this state is that a very large proportion of the electrons completely fill the lower energy levels, and are unable to take part in any physical processes until excited out of these levels.

DEGENERATE OSCILLATING SYSTEM. A vibrating system with several **degrees of freedom** in which the frequencies associated with two or more degrees of freedom may be equal in magnitude.

DEGENERATE SEMICONDUCTOR. See **semiconductor, degenerate.**

DEGENERATE STATE. In quantum mechanics, when different states of motion correspond to the same **energy level,** the states are said to be degenerate. The degeneracy can often be removed by the application of a perturbing field with the effective introduction of a new quantum condition, i.e.,. the breakup of one **eigenvalue** into several.

DEGENERATION. Same as negative feedback. (See **feedback, negative.**)

DEGRADATION. Loss of energy by **collision.** Neutron degradation is also called **moderation.**

DEGRADATION OF ENERGY, LAW OF. A name applied to the second law of thermodynamics (see **thermodynamics, second law of**), because of the statement that the **entropy** of an isolated system is increased by irreversible processes involving energy changes, and that therefore, the sum of the available energy tends to decrease.

DEGRADING OF BAND. See **band, shading of.**

DEGREE. (1) A unit of angular measure; 2π radians equal 360°; (2) the **degree** of a **polynomial** is the exponent of its highest power; (3) the **degree** of a **differential equation** is the highest power of a derivative in it. (4) A unit of temperature or temperature difference.

DEGREE OF DISSOCIATION. The fraction of **electrolyte** dissociated into **ions.**

DEGREE OF FREEDOM. See **freedom, degree of.**

DE HAAS-VAN ALPHEN EFFECT. At very low temperatures the **diamagnetic susceptibility** of the **conduction electrons** of many complex metals shows a periodic variation with changes of the applied magnetic field component perpendicular to the principal axis of the crystal. The theory of the effect is complicated, but it is related to the shape of the **Brillouin zones, arising** apparently from small pockets of electrons or **holes.**

DEHUMIDIFICATION. A process used in air-conditioning in which air partially saturated with water is cooled to below the **dew point,** so that part of the water vapor is condensed.

DEIONIZATION POTENTIAL. The potential at which conduction in a **gas-discharge tube** stops, due to the cessation of ionization.

DEIONIZATION TIME. The time required for the grid of a **gas-discharge tube** to regain control after anode-current interruption. To be exact, the ionization and deionization times of a gas tube should be presented as families of curves relating such factors as condensed-mercury temperature, anode and grid currents, anode and grid voltages, and regulation of the grid current.

DEKAGRAM. Ten **grams.**

DEKALITER. Ten **liters.**

DEKAMETER. Ten **meters.**

DEKATRON. A cold-cathode **counting tube.**

DEL. The **differential operator** used in vector analysis, sometimes also called **nabla,** and usually written as ∇. In Cartesian coordinates it is

$$\left(\mathbf{i}\frac{\partial}{\partial x} + \mathbf{j}\frac{\partial}{\partial y} + \mathbf{k}\frac{\partial}{\partial z}\right).$$

When applied to a scalar function it gives the **gradient;** to vectors, it can give the **divergence** or the **curl.** There are six possible combinations where the operator is applied twice, although two of them equal zero identically. If ϕ is a scalar and $\mathbf{V}$ a vector, they are:

(1) $\nabla^2\phi$, the **Laplacian**; (2) $\nabla^2\mathbf{V}$; (3) $\nabla(\nabla\cdot\mathbf{V})$; (4) $\nabla \times (\nabla \times \mathbf{V}) = (\nabla\cdot\mathbf{V}) - \nabla\cdot\nabla\mathbf{V}$; (5) $\nabla \times \nabla\phi = 0$; (6) $\nabla\cdot\nabla \times \mathbf{V} = 0$.

DELAY AUTOMATIC VOLUME CONTROL. **Automatic volume control** which is designed to act only on signals which exceed a certain predetermined value.

DELAY CIRCUIT. A circuit used to cause the delay for a certain period of time of the starting of a **waveform.**

DELAY DISTORTION. See **distortion, delay.**

DELAY EQUALIZER. An **equalizer** which is used to correct for delay distortion (see **distortion, delay**) in transmission systems

DELAY-LINE MEMORY. In computer terminology, a type of **circulating memory** in which a delay line is the major element in the circulation path.

DELAY-LINE REGISTER. An acoustic or electric delay-line, usually one or an integral number of words long, together with input, output, and circulation circuits.

DELAYED ALPHA PARTICLES. See ***α*-particles, delayed.**

DELAYED COINCIDENCE. See **coincidence, delayed.**

DELAYED NEUTRONS. See **neutrons, delayed.**

DELBRÜCK SCATTERING. See **scattering, Delbrück.**

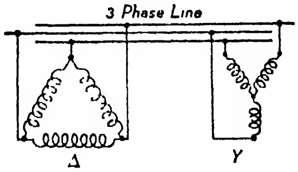
DELIQUESCENCE. The property of a substance whereby it absorbs water vapor from the atmosphere, eventually becoming a solution. The condition for it is that the concentrated solution has a vapor pressure smaller than that of the water vapor in the atmosphere. The process continues until these vapor pressures become equal.

DELLINGER EFFECT. The sudden disappearance of **skywave** signals as a result of greatly increased ionization in the **ionosphere** due to solar storms. The effect may last from ten minutes to several hours.

DELOCALIZATION ENERGY See **resonance energy.**

DELTA. (1) Finite difference (Δ or δ). (2) Symbol for a double bond. (This is a common chemical usage (Δ).) (3) Symbol for application of heat in the course of a chemical reaction (Δ). (4) Angle of deviation (δ), angle of minimum deviation (δ_m). (5) Deviation (δ). (6) Difference in phase (δ). (7) Total elongation (deflection) (δ). (8) Optical length (Δ). (9) Acoustic conductivity of an opening (δ). (10) Sag or deflection of a beam (δ). (11) Distance between adjacent foci of two lens units (Δ). (12) Piezoelectric strain constant or modulus (δ). (13) Electronic state of molecule having a Λ-value of 2 (Δ).

DELTA CONNECTION. The Delta connection is one of the two most frequently used ways of connecting a three-phase **alternating-current circuit.** The other is the Y connection. A three-phase machine has three coils. These coils have six ends which must, in some way, be connected to the three wires of a three-phase circuit. The Delta connection, as illustrated in the accompanying figure, has



Delta connection and Y connection compared

the coils connected at three points corresponding to the three-phase circuit. When this is compared with the Y connection, it will become apparent that the line voltage in Delta connection equals the coil voltage, and that the line current in Y connection equals coil **current.** For a balanced Delta load the line current is $\sqrt{3}$ times the phase (or coil) current.

DELTA FUNCTION. See **Dirac delta function; Kronecker delta.**

DELTA-MATCHING TRANSFORMER. A matching network (see **network, matching**) used between half-wave antennas and two-wire transmission lines The antenna is not cut, as its center and the transmission lines are fanned out before connection to it. The resultant delta-shaped pattern gives the network its name.

DELTA NETWORK. See **network, delta.**

DELTA RAY. An electron that is ejected by recoil when a rapidly-moving charged particle, e.g, an α-particle, passes through matter. The use of the term delta ray is sometimes extended to apply not only to electrons, but to any secondary ionizing particles ejected by recoil when a primary ionizing particle passes through matter.

DELTAMAX. Trade name for an oriented 50% nickel, 50% iron alloy.

DEMAGNITIZATION FACTOR. See **depolarization factor, demagnetizing field.**

DEMAGNETIZING FIELD. A body of magnetic material subject to an **applied magnetizing force H_a** is acted upon by a net magnetizing force,

$$H = H_a - \Delta H$$

where the demagnetizing field **ΔH** is interpreted as being due to the poles induced on the surface of the body. In the case of a permanent magnet with $H_a - 0$, the demagnetizing field is readily seen to be the field of the magnet itself, which always has such a direction as to oppose the magnetization. The existence of a demagnetizing field is a necessary consequence of the fact that energy is stored in the field external to the magnetized body, and that the sum of this energy and the internal energy must be minimized at equilibrium. The demagnetizing field is approximately proportional to the **magnetic moment density:**

$$\Delta H = NM = \frac{N}{4\pi}\left(\frac{B}{\gamma m} - H\right)$$

with the factor 4π deleted for rationalized units. The proportionality factor N is called the demagnetizing factor, and depends primarily on the shape of the body.

DEMAL SOLUTION. A solution which contains one **gram-equivalent** of solute per cubic decimeter of solution. It is slightly weaker than a normal solution, in the ratio of the magnitude of the liter to the cubic decimeter. The unit *demal* is used in conductivity measurements.

DEMODULATION (OR DETECTION). The process by which information is derived from a modulated **waveform** about the signal imparted to the waveform in **modulation.**

DEMODULATION, ENHANCED - CARRIER. An amplitude-demodulation system in which a synchronized local carrier of the proper phase is added to the **demodulator.** This has the effect of materially reducing the distortion produced in the demodulation process.

DEMODULATOR. A device to effect the process of **demodulation.**

DEMODULATOR, DIODE. A rectifier demodulator, sometimes an envelope demodulator. (See **demodulator, rectifier;** and **demodulator, envelope.**)

DEMODULATOR, ENVELOPE. A rectifier demodulator (see **demodulator, rectifier**)

whose output is shunted by a capacitance, thus causing the output to be proportional to the peaks of the rectified amplitude-modulated carrier. If low distortion is desired, this process may be used only where the ratio of carrier to the highest modulation frequency is quite large.

DEMODULATOR, FREQUENCY. A device which will produce an output proportional to the variation of the instantaneous frequency of the input voltage. Ideally it will be insensitive to variations in the **amplitude** of the input wave.

DEMODULATOR, PRODUCT. A device whose output is the product of its two inputs, these being the amplitude-modulated carrier and a locally-generated voltage of **carrier frequency.** This is basically the same device as a product modulator (see **modulator, product**), and with proper filtering, can produce an output proportional to the original modulation.

DEMODULATOR, RECTIFIER. A device consisting of a **diode** or diodes through which the amplitude-modulated carrier is passed. The resulting rectified output has an average value proportional to the original **modulation.** With conditions approximating a perfect **rectifier**, the linearity of the device is quite good below 10% modulation.

DEMODULATOR, SQUARE-LAW. A device whose output voltage is proportional to the square of its input voltage. An amplitude-modulated carrier passing through such a device produces an output containing the original modulation signal as well as distortion products. The distortion products increase rapidly as the percent modulation increases.

DE MOIVRE THEOREM. Any power of a **complex number** in polar form is given by

$$[r(\cos\theta + i\sin\theta)]^n = r^n(\cos n\theta + i\sin n\theta).$$

This formula holds when n is a positive or a negative integer. It also holds when n is fractional, but may then be written in the more general form:

$$[r(\cos\theta + i\sin\theta)]^{1/n} = r^{1/n}\left[\cos\frac{\theta + k\cdot 360°}{n} + i\sin\frac{\theta + k\cdot 360°}{n}\right],$$

where k takes the values of $0, 1, 2, \cdots, (n-1)$ and where $r^{1/n}$ denotes the principal nth **root** of r. The theorem gives all of the nth **roots** of any number.

DEMOUNTABLE TUBE. An **electron tube** which may be taken apart for inspection or repair. Usually limited to large-sized units which are continuously-pumped during operation.

DEMPSTER POSITIVE RAY ANALYSIS. A method of separating particles of different **charge-to-mass ratios.** The particles are caused to fall through a definite potential difference. A narrow bundle is separated out by a slit and bent into a semicircle by a strong magnetic field; the rays then pass through a second slit and fall on a plate connected to an electrometer. The potential difference V, the magnetic field H, and the radius of curvature r determine the charge-to-mass ratio, since

$$\frac{q}{m} = \frac{2V}{H^2r^2}.$$

DENDRITE. A crystal, usually produced by solidification of liquid, and characterized by a treelike structure with many branches.

DENSE SET. A set whose **accumulation points** include all points of the complement.

DENSIMETER. Any instrument used to determine **density.**

DENSITOMETER. An instrument for the measurement of **optical density** (photographic transmission, photographic reflection, visual transmission, etc.) of a material.

DENSITOMETER, BAIRD. See **Baird densitometer.**

DENSITY. (1) The ratio of the mass of a homogeneous body to its volume. The average density of a non-homogeneous body is similarly defined, but the density of any portion of such a body is the ratio of the mass of that portion to its volume. (2) In length-force-time systems of units, the term density is sometimes used to denote weight per unit volume, rather than mass per unit volume. (3) By analogy, the ratio of the number of particles or total amount of such a quantity as energy or momentum, carried by or contained in a volume to that volume. **Thus one**

speaks of energy density, electron density, charge density, etc.

DENSITY, ABSOLUTE. Mass per unit volume, understood to be expressed in grams per cubic centimeter when no units are specified.

DENSITY, DIFFUSE. A quantity defined as the logarithm of the reciprocal of the diffuse transmittance. (See **transmittance, diffuse.**)

DENSITY, LUMINOUS. The luminous energy (see **energy, luminous**) found in a unit volume of space.

DENSITY, NORMAL. The mass of unit volume of a gas under standard conditions (temperature at 0°C, pressure at 760 millimeters of mercury, at sea level, and at 45° latitude).

DENSITY OF MATTER IN UNIVERSE. Values of the average density of matter in the universe have been quoted between 10^{-26} and 10^{-30} g cm^{-3}.

DENSITY, PHOTOGRAPHIC. See **optical density, photographic.**

DENSITY, RADIANT. The radiant energy (see **energy, radiant**) found in a unit volume of space.

DENSITY, RELATIVE. The ratio of the mass of a given volume of a substance to that of the same volume of another substance chosen as a standard. (Cf **specific gravity.**)

DENSITY, SPECULAR. The logarithm of the reciprocal of the specular transmittance. (See **transmittance, specular.**)

DENUMERABLE, DENUMERABLE SET. A **set,** whose points can be placed in one-to-one correspondence with the sequence of positive integers. Otherwise, the set is non-denumerable.

DEPLETION LAYER (IN A SEMICONDUCTOR). A region in which the mobile **carrier** charge density is insufficient to neutralize the net fixed charge density of **donors** and **acceptors.**

DEPOLARIZATION. The process of removing polarization. Examples are: (1) depolarization of an electric cell most commonly a dry cell, as effected by the action of a **depolarizer;** (2) electric depolarization or demagnetization as effected by a **depolarization field,** and as related by the **depolarization factor;** (3) depolarization of light as accomplished by a device for **resolution of polarized light.**

DEPOLARIZATION FACTOR OR DEMAGNETIZATION FACTOR. The factor N relating the **depolarization field E** to the polarization P of the specimen, by the relation $\mathbf{E} = -NP$. For example, the depolarization factor for a sphere is $4\pi/3$ about any axis. For a circular cylinder (long) it is 2π about a transverse axis, and 0 about a longitudinal axis. For a thin slab, it is 4π about a normal axis, and 0 about an axis in a plane of the slab, etc. All the factors are given in unrationalized units. (See **demagnetizing field.**)

DEPOLARIZATION FIELD. When an electric or magnetic field is applied to a macroscopic specimen, the field acting on a given atom contains a contribution due to the charges or poles induced on the surface of the specimen. This field opposes the external applied field, and hence tends to reduce the **polarization** of the material. (See **demagnetizing field.**)

DEPOLARIZATION OF METAL DEPOSITION. If a metal being deposited by **electrolysis** can form a compound with the cathode, which compound dissolves in the cathode material, then deposition can occur at a potential less cathodic than the reversible value.

DEPOLARIZER. An agent or means for the prevention or removal of **polarization.** Thus, an electrical depolarizer is a substance added to a "dry" battery (a cell used to generate electricity by a chemical reaction) to prevent the accumulation of reaction products that interfere with the functioning of the cell. The term electrical depolarizer is also applied to a diaphragm placed in an electrolytic cell to prevent mixing of the reaction products. An optical depolarizer is a device for the **resolution of polarized light.**

DEPOSITION, ELECTRICAL. The deposition of elements from solutions of their compounds upon an electrode in an **electrolytic cell.** One **faraday** is required for the deposition of one gram-equivalent of any substance.

DEPRESSION. A region over which atmospheric pressure is lower than surrounding re-

gions. A depression, of necessity, has cyclonic winds. (See **cyclone.**)

DEPTH. In radiation physics, the radiation dose delivered at a particular depth beneath the surface of the body. It is usually expressed as percentage of surface dose or as percentage of air dose. (See **dose,** and **dose, air.**)

DEPTH OF FIELD. A photographic term referring to the distance over which satisfactory definition is obtained when the lens is in focus for a certain distance. If, for example, a lens is in focus for an object at a distance of 25 feet and the definition is satisfactory on objects from 20–40 feet, the depth of field extends from 20–40 feet. Depth of field is frequently but incorrectly termed depth of focus, which is the range of image distances corresponding to the range of object distances covered by the depth of field.

DERIVATIVE. The instantaneous rate of change of a function with respect to its independent variable. The usual symbol is dy/dx but y', $f'(x)$, and other designations are also used. If the function $y = f(x)$ is plotted in rectangular coordinates, the slope of the curve at the point $x = x_0$ is its **derivative,** dy/dx, at that point, and is

$$\left(\frac{dy}{dx}\right)_{x_0} = \underset{\Delta x \to 0}{\text{Limit}} \frac{f(x + \Delta x) - f(x)}{\Delta x}.$$

(See also **derivative, partial** and **derivative, total.**) The symbol $\dot{y}$ is often used to indicate dy/dt where t is time.

DERIVATIVE, DIRECTIONAL. If **u** is a **unit vector,** the quantity $\mathbf{u} \cdot \nabla\phi$, its **scalar product** with the **gradient** of a scalar function, is the rate of change of ϕ in the direction of **u** or the **directional derivative** of ϕ.

DERIVATIVE, HIGHER. The **derivative** of the derivative of a function $y = f(x)$. The derivative of the second order is written in various forms, thus: d^2y/dx^2, D_x^2y, $f''(x)$, f_{xx}, y''. Similar notation is used for derivatives of third and higher order. In general, the nth derivative is the derivative of the $(n - 1)$th derivative and it could be designated as d^ny/dx^n, D_x^ny, $f^{(n)}(x)$, or $y^{(n)}$.

DERIVATIVE, PARTIAL. Let $u = f(x, y, z, \cdots)$ be a function of two or more variables. Keep all the variables constant except one. x for example, and give x an increment Δx. If Δu is the corresponding increment in u, then the **limit** $\lim_{x \to 0} \left(\frac{\Delta u}{\Delta x}\right)$ is the **partial derivative** of u with respect to x. It is denoted by $\frac{\partial u}{\partial x}$, u_x, or, especially in thermodynamics, by $\left(\frac{\partial u}{\partial x}\right)_{y,z,\cdots}$ where the subscripts indicate the variables held constant during the differentiation. The partial derivatives $\partial u/\partial y$, $\partial u/\partial z$, etc., are defined similarly.

In general, the partial derivatives are themselves functions of x or y or both. They may thus be differentiated again to obtain partial derivatives of higher order:

$$\frac{\partial^2 u}{\partial x^2} = \frac{\partial}{\partial x}\left(\frac{\partial u}{\partial x}\right); \quad \frac{\partial^2 u}{\partial x \partial y} = \frac{\partial}{\partial x}\left(\frac{\partial u}{\partial y}\right);$$

$$\frac{\partial^2 u}{\partial y \partial x} = \frac{\partial}{\partial y}\left(\frac{\partial u}{\partial x}\right); \quad \frac{\partial^3 u}{\partial x^3} = \frac{\partial}{\partial x}\left(\frac{\partial^2 u}{\partial x^2}\right); \text{ etc.}$$

The abbreviated notation u_{xx}, u_{xy}, u_{xxz}, etc., is often used.

If the mixed derivatives, u_{xy} and u_{yx}, are continuous, then they are equal.

See also **derivative, total.**

DERIVATIVE, TOTAL. If $u = f(x, y, z, \cdots)$ is a function of several variables, each of which itself is a function of a single independent variable t, then the **total derivative** is

$$\frac{du}{dt} = \frac{\partial u}{\partial x}\frac{dx}{dt} + \frac{\partial u}{\partial y}\frac{dy}{dt} + \frac{\partial u}{\partial z}\frac{dz}{dt} + \cdots.$$

DESCARTES LAWS OF REFRACTION. The incident and refracted rays (a) are in the same plane with the normal to the surface, (b) they lie on opposite sides of it, and (c) the sines of their inclinations to it bear a constant ratio to one another, the ratio depending only on the two media involved, **not** on the angles with the normal. Descartes applied these laws only to ordinary isotropic media.

DESCARTES RULE OF SIGNS. If in passing from one coefficient of a **polynomial equation** to the next, there is a change of sign from plus to minus or from minus to plus,

this is called a variation of sign; a succession of two like signs, either both plus or both minus is called a permanence of signs. The number of positive roots of a polynomial equation $P(x) = 0$ with real coefficients is not greater than the number of variations of sign in the polynomial, and the number of negative roots is not greater than the number of variations of sign in the polynomial $P(-x)$.

DESENSITIZATION. The action of rendering a photographic emulsion or other material less subject to reactions brought about by light.

DE SITTER UNIVERSE. Model of the universe in which the interval between two events is given by that for the **Einstein universe** with, however, dt^2 replaced by

$$\left(1 - \frac{r^2}{R^2}\right) dt^2.$$

May be regarded as the four-dimensional surface of a sphere imbedded in five dimensions.

DESLANDRES, LAWS OF. 1st Law. In **band spectra**, the oscillation **frequencies** of the lines starting from one head form arithmetical series. More than one such series can proceed from the same head.

2nd Law. The differences in frequency of the heads of the bands in each group form an arithmetical series, but the arrangement of the heads is reversed from that of the lines forming each band.

DESORPTION. The reverse of absorption or adsorption, as in the release of one substance which has been "taken into" another by a physical process, or the release of a substance which has been held in concentrated form upon a surface.

DESTRUCTION OPERATOR. An operator which, applied to a state vector ψ_n describing a system in which n particles are present, yields a state vector ψ_{n-1} which describes the system with $n - 1$ particles present.

DETECTOR. (1) A **demodulator.** (2) A device used in a **bridge** circuit on other measuring device to indicate the existence of a null or balance condition. (3) Any device which indicates the presence of an entity of interest, such as radiant energy, without yielding a quantitative measurement.

DETECTOR, BALANCED. (1) **Demodulator** for **frequency-modulation** systems. In one form the output consists of the rectified difference of the two voltages produced across two resonant circuits, one circuit being tuned slightly above the **carrier frequency** and the other slightly below. (2) A detector for bridge or other null circuits, which include a balanced amplifier. (See **amplifier, balanced.**)

DETECTOR, CARBORUNDUM. An early **crystal rectifier** which used the semiconductor, carborundum.

DETECTOR, CHARGED POINT. A radiation **counter** which utilizes the principle that the applied voltage necessary to produce a breakdown discharge from a charged conducting-point can be greatly varied by irradiating the gas in the neighborhood of the point with, for example, **x-rays or α particles.**

DETECTOR, GRID-LEAK. A type of envelope-demodulator (see **demodulator, envelope**) which employs the **grid** of a vacuum tube as the **rectifier.** The grid circuit consists of the input, the "grid-leak" resistor, and the grid-ground terminals of the tube. A capacitor is placed across the resistor so that the reciprocal of their **time constant** is less than the highest **modulating-frequency,** and larger than the **carrier-frequency.** This apparatus is more sensitive than the basic diode envelope-demodulator, because the equivalent diode signal is amplified by the tube However, because of the inherently-poor operating point required for this mode of operation, the distortion is generally quite high.

DETECTOR, HOMODYNE. A product amplitude-demodulator (see **demodulator, product**). When provided with suitable accessory circuitry, it may also be used as a frequency-modulation **discriminator.**

DETECTOR, INFINITE IMPEDANCE. A form of the plate detector (see **detector, plate**) in which the detector load resistance is connected in the cathode circuit. The grid is negative at all times, and thus draws no current. The **negative feedback** action of the **cathode follower** causes the distortion to be quite low.

DETECTOR, INFRARED. Since infrared radiation is not visible to the eye, it must

be detected by some physical device. These fall in a number of classes.

I. Heat Engine. A device which is warmed by the absorbed radiation and this rise in temperature results in some observable phenomenon.

a. Thermocouple. Rise in temperature produces an emf.
b. Bolometer and Thermistor. A rise in temperature changes the resistance of a conductor through which a small electric current flows.
c. Pneumatic Device. A rise in temperature increases the pressure (and volume) of a small volume of gas and this change is observed.

Such detectors are independent of the wavelength of the radiation in so far as the receiving surface is "black."

II. Photoconductive. Certain semiconductors become more conductive when irradiated with certain radiations. The wavelength must be sufficiently short, that is, the photons sufficiently energetic, to lift an electron from a bound level to a conduction level. Such detectors are very wavelength-sensitive. Lead sulphide and lead telluride properly sensitized with a suitable inpurity, commonly oxygen, are well known photoconductive detectors. This field is presently (1956) being rapidly developed and new and better photoconductive detectors are appearing.

III. Photoemissive. Most surfaces when irradiated with radiation of sufficiently short wavelength (sufficiently energetic photons) emit electrons which may be observed in various ways. Only few surfaces respond to the weak photons associated with short infrared radiation. The surface which emits electrons when irradiated with the longest infrared radiation which may be detected by this method (about 1.2 microns) is a special silver, oxygen, cesium surface (1956).

IV. Photographic. Photographic emulsions when dyed with certain dyes become sensitive to infrared radiation out to about 1.2 microns.

V. A considerable number of other possible infrared detectors are presently (1956) being studied. Some of these offer considerable promise but have not yet shown superiority over those mentioned above.

DETECTOR, OSCILLATING (BEATNOTE DETECTOR). A **demodulator** which is either oscillating or fed from an external **oscillator.** In either case the frequency of oscillation is made to be sufficiently close to the unmodulated carrier being received so that an audible **heterodyne frequency** is produced.

DETECTOR, PERIKON. An early form of **crystal rectifier** used as a detector.

DETECTOR, PHASE-SENSITIVE. A **detector** (2) which responds only to input signals having the same frequency as the control signal and a specified phase relative to that signal.

DETECTOR, PLATE. Sometimes called the "anode bend detector," it involves operation towards the point of plate-current cut-off so that non-linearity occurs, thus giving **rectification.** Sensitivity is generally fairly low, and distortion is quite high

DETECTOR, RATIO. A f-m **discriminator** which utilizes the ratio of two intermediate-frequency voltages whose relative magnitudes are a function of frequency, rather than the difference of those potentials as in the case of the Armstrong discriminator circuit.

DETECTOR, REGENERATIVE. A **demodulator** whose **gain** or **conversion ratio** is increased by the addition of positive **feedback** or **regeneration** at the carrier frequency. The **sensitivity,** small-signal **selectivity,** and distortion are increased over that found in a detector without regeneration

DETECTOR, SELF-QUENCHING. A superregenerative **detector** which is made to squegg (see **squegging**) at a supersonic frequency, thus eliminating the necessity for an external **quenching oscillator.**

DETECTOR, SILICON. A silicon **semiconductor** rectifier or diode.

DETECTOR, SWITCH. A **detector** which extracts information from the input waveform only at instants determined by a selector **pulse.**

DETECTOR, SYNCHRONOUS. A **detector** (2) which is sensitive only to signals at or near to a given frequency. This frequency is identical with the frequency of a control signal supplied independently. Synchronous de-

tectors are used in bridge and other null circuits as anti-noise devices. They are phase sensitive as well as frequency selective. One form consists of a balanced amplifier in which the signal is applied to the grids of two tubes, while the control signal is supplied to their plates or to an additional grid. The difference of their output currents, or of simple functions of their output currents is then measured. Sometimes called a lock-in amplifier. Other forms use rectifiers in a bridge circuit or an **electrodynamometer** with its two coils separately excited.

DETECTOR, THERMAL. See **thermal detector.**

DETECTOR, TRAVELING. A device for measuring electric field intensity in a **waveguide** as a function of distance along the guide.

DETERMINANT. A square **array** containing n^2 elements and said to be of **order** n. It may be developed to give a single number or, more generally, a linear combination of products. To evaluate a determinant of order n, form all products, $n!$ in number, by taking one element A_{ik} from each row and column. The subscripts in the products, i, i', i'', $\cdots$ and k, k', k'', $\cdots$ will then include all **permutations** of the numbers 1, 2, $\cdots$, n. Rearrange the subscripts i so that these numbers are in their natural order. The second subscripts k will then require either an even number or an odd number of interchanges to return them also to the natural order 1, 2, $\cdots$, n. The value of the determinant is defined as

$$|A| = \det A = \Sigma(-1)^h A_{1k_1} A_{2k_2} \cdots A_{nk_n}$$

where the summation is made over all permutations k_1, k_2, $\cdots$ of the subscripts k and h is the number of interchanges needed to restore the natural order.

Another method of evaluation is the **Laplace development.** For further properties of determinants see **minor, cofactor, rank, Cramer rule, linear equation.** (See also **Gram determinant, Jacobian, secular determinant, Wronskian.**)

DETERMINATE STRUCTURE. Any structure in which the reactions and stresses can be found by means of the equations of **statics** only is a determinate structure. If a sufficient number of such equations cannot be set up from known conditions, the structure is not statically determinate. If the number of possible independent equations is greater than the number of unknown stresses and reactions, the structure is overdetermined.

DEUTERIUM. The isotope of hydrogen of atomic weight 2.0147.

DEUTERON. The nucleus of the **deuterium** atom (the atom of the hydrogen isotope of mass number 2).

DEVELOPER. A reducing agent used in the **development** of films and other materials containing photosensitive substances which have been exposed to the action of light.

DEVELOPMENT. (1) In general, development is the growth and differentiation in the structure of an entity, such as a crystal or an organism, and the acquisition of new characteristics.

In photography, development is a process whereby the exposed light-sensitive film or other material is treated with a chemical agent to reduce or otherwise change enough of the photosensitive substance (such as silver bromide to free silver) in order to produce a visible (reverse) image of the object photographed. This step is necessary because the initial exposure merely transforms enough of the photosensitive substance to serve as a starting point (probably as a system of nuclei) for the development.

(2) In descriptive geometry, the reduction of any ruled surface to a plane figure which may be bent or rolled, without distortion, into the original surface.

DEVIATION. (1) See **average deviation; standard deviation.** (2) The angle through which a light ray is bent by **refraction** or **diffraction.**

DEVIATION, FREQUENCY. In phase modulation and frequency modulation (see **modulation, phase;** and **modulation, frequency**) the peak difference between the instantaneous frequency of the modulated wave and the carrier frequency.

DEVIATION LOSS, ANGULAR. Of a **transducer** used for sound emission or reception, an expression, in **decibels,** of the ratio of

the reference **response** observed on the principal axis to the transducer response at a specified angle from the principal axis.

DEVIATION, MINIMUM ANGLE OF. The angle of deviation in a **prism** is a minimum if the entrant and exit rays make equal angles with the surfaces of the prism This angle is of particular interest in prism spectroscopes because it can be easily determined and a relatively simple formula connects the angle of the prism (A), the angle of minimum deviation (D) and the index of refraction (n) of the prism.

$$n = \frac{\sin\left(\frac{A + D}{2}\right)}{\sin\left(\frac{A}{2}\right)}.$$

DEVIATION, PHASE. In phase and frequency modulation, the peak difference between the instantaneous angle of the modulated wave and the angle of the carrier

DEVIATION RATIO. In a frequency-modulation system (see **modulation, frequency**), the ratio of the maximum frequency deviation to the maximum **modulating frequency** of the system.

DEVIATION SENSITIVITY. The least frequency deviation (see **deviation, frequency**) that produces a specified output power.

"DEVITRIFICATION." **Crystallization** of glass causing embrittlement and loss of transparency. The process occurs most rapidly in the temperature range in which the viscosity of the glass is between 10^3 and 10^8 poises and this temperature range is therefore called the "devitrification range."

DEW. If air in contact with any surface is cooled at the surface to a temperature below its **dew point,** some of the water vapor present in the air will condense onto the cool surface as liquid water or dew. When temperatures are below freezing, hoarfrost forms instead.

DEW POINT. The temperature at which the actual content of water vapor in the atmosphere is sufficient to saturate the air with water vapor. If the atmosphere contains much water vapor the dew point is higher than in the case of drier air, so that the dew point is an indication of the humidity of the atmosphere.

DEW-POINT HYGROMETER. See **hygrometer.**

DEW-POINT METHOD. See **vapor pressure, methods of measurement.**

DEWAR FLASK. A vessel with a double wall, in which the region between the walls has been evacuated, and in which the walls bordering this space have been silvered. With this construction the region within the inner container is very well insulated from the outside The vessel is commonly used for storage of liquefied gases.

D-F. Abbreviation for **direction finder.**

D-G ACHROMATISM. A correction for chromatic aberration based on the yellow **D** and blue **G lines** instead of the customary **C** and **F lines.** D-G achromatism is common for photographic **achromats.**

DIACAUSTIC. A **caustic** caused by refraction.

DIACTINISM. The property of transmitting chemically active radiation

DIAGONAL. See **matrix, diagonal.**

DIALOGUE EQUALIZER. A **filter** sometimes used to decrease the low-frequency response of a wide-range audio system being used for speech.

DIALYSIS. The process of separating compounds or materials by the difference in their rates of diffusion through a colloidal semipermeable **membrane.** Thus, sodium chloride diffuses eleven times as fast as tannin and twenty-one times as fast as albumin. (See **dialyzer.**)

DIALYSIS, ELECTRO. **Dialysis** which is accelerated or otherwise modified by placing the semipermeable **membrane** between electrodes to which a direct-current potential is applied.

DIALYZER. An apparatus for carrying out a **dialysis,** usually consisting of two chambers separated by a semipermeable **membrane** of parchment paper latex, animal tissue, or other colloid. In one chamber the solution is placed, and in the other, the pure **solvent.** Crystalline substances diffuse from the solu-

tion through the membrane and into the solvent much more rapidly than amorphous substances, colloids or large molecules

DIAMAGNETIC. Diamagnetic substances have a negative magnetic **susceptibility** and a **permeability** less than unity.

DIAMAGNETIC SUSCEPTIBILITY OF CONDUCTION ELECTRONS. The free **electron gas** in a metal is diamagnetic in virtue of its charge, with a volume susceptibility

$$\chi_d = N\mu_B{}^2/2kT_F$$

where μ_B is the **Bohr magneton,** T_F the **Fermi temperature,** N the number of electrons per unit volume, and k the **Boltzmann constant.** This susceptibility is distinct from the **paramagnetic susceptibility** of the electrons, and according to the **band theory of solids** varies inversely as the effective mass. If the effective mass is very small, more exact theory leads to the phenomena of the **de Haas-van Alphen effect.**

DIAMAGNETISM. Diamagnetism is an interesting phenomenon found in many substances; the **magnetization** opposes the **magnetizing force,** i.e., the susceptibility is negative, or $\mu_s < 1$. All materials exhibit diamagnetism which results from the **Larmor precession** of spinning or rotating charges in the magnetic field. In paramagnetic materials, the effect of dipole orientation in the field is greater than that of the intrinsic diamagnetism. (See **Langevin theory of diamagnetism.**)

DIAMAGNETISM, LANGEVIN FORMULA. The equation for the **diamagnetic susceptibility** for an assembly of N atoms per unit volume is

$$\chi = -\frac{Ze^2N}{6mc^2}\overline{r^2}$$

where $\overline{r^2}$ is the mean square radial distance of the electrons from their nuclei, and Z is the atomic number (e, m, c as usual). This formula was originally derived classically by Langevin, and corrected quantum-mechanically by Pauli.

DIAMAGNETISM, LANGEVIN THEORY OF. See **Langevin theory of diamagnetism.**

DIAMOD. The name applied to a form of **rectifier modulator.**

DIAMOND ANTENNA. See **antenna, diamond.**

DIAMOND-GRID RADIATOR ANTENNA. See **antenna, diamond-grid radiator.**

DIAPHANOMETER. An instrument used to measure the degree of transparency of solids, liquids, or gases.

DIAPHRAGM. (1) Usually a separating wall which transmits or passes substances or stresses selectively. Thus, a diaphragm with many small openings is used in electrolytic cells to permit passage of ions and yet to segregate reaction products. Diaphragms with a single opening, that may be adjustable in size, are used to control flow of substances or radiations, as in the camera. (2) In acoustics, a vibrating element, as in the loudspeaker, telephone and other sound-sources; and the diaphragm of the human ear.

DIATHERMANOUS. Highly transparent to infrared radiation.

DIATHERMY. The use of high-frequency electromagnetic waves to generate heat in living tissue for therapeutic purposes.

DIATHERMY MACHINE. An **oscillator,** usually electronic, used to generate the high-frequency voltages used in **diathermy.**

DICHROISM. The property of exhibiting two colors, especially of exhibiting one color when viewed in reflected light and another when viewed in transmitted light, as in the case of solutions of chlorophyll. Substances which have this property are termed dichroic.

DICHROISM, CIRCULAR. See **electric and magnetic double refraction.**

DICHROMATISM. (1) A type of color blindness in which the eye can distinguish two and only two colors. (2) A substance with two broad, but not equally deep, absorption bands in the visible may appear to have a different color as observed by transmitted light depending on the thickness of the plate of material. Such a material is called dichromatic.

DICROSCOPIC EYEPIECE. An eyepiece for a **polariscope** or polarizing microscope which gives a comparison view of the same object or field under illumination by the two complementary rays of polarized light.

DIDYMIUM GLASS. Most absorption bands of solid materials are broad with not sharp edges. However, glass tinted with mixed oxides of **neodymium** and **praseodymium** has very narrow and sharp absorption bands. One in particular falls at the wavelength of yellow sodium light, so that the glass, which is only faintly tinted to white light, is almost opaque to the yellow sodium light.

DIELECTRIC. A material characterized by its relatively poor electrical conductivity, hence an insulator. For alternating fields, the dielectric nature of a substance gives rise to a **displacement current,** which leads the field variation by a 90° phase angle, whereas the conductivity of the material gives rise to an in-phase current. Since the (capacitive) displacement current increases with frequency, a substance may be a "poor" dielectric at low frequency, but "good" at high frequencies. (See **flux, electric; dielectric constant;** and **polarization.**)

DIELECTRIC ABSORPTION. The persistence of electric polarization in some **dielectrics** after the removal of the polarizing electric field. When a **condenser** with glass plates is connected with a **battery,** the charging current may last, though gradually decreasing, for some minutes or hours, and when the charged condenser is short-circuited, the discharge current may not cease entirely with the first rush. After a **Leyden jar** has been discharged and allowed to stand disconnected for a time, another, smaller spark can usually be obtained from it. This is called a "residual" charge.

By melting mixtures of wax and allowing them to harden in a strong electric field, Eguchi (Japan, 1925) succeeded in obtaining dielectric absorption which persisted almost undiminished for several years. Such a permanently polarized body, singularly analogous to a permanent magnet, has been termed an **"electret."**

DIELECTRIC, ANISOTROPIC. In crystals, the various physical properties often depend upon the direction of an applied field, or the direction of propagation of a wave, etc. This dependence of properties on direction is called "anisotropy." An anisotropic dielectric has different dielectric constants for electric fields applied parallel to the various crystal axes. In an anisotropic dielectric, the (scalar) dielectric constant, appropriate to isotropic materials, is replaced by a **tensor** which relates the electric induction and the electric field strength.

DIELECTRIC ANTENNA. See **antenna, dielectric.**

DIELECTRIC BREAKDOWN. Field strengths of the order of 10^6 volts/cm can cause breakdown in crystals of alkali halides. The effect is attributable to the excitation of further conduction electrons by electrons already moving in the **conduction band** and accelerated by the field.

DIELECTRIC CONSTANT. (Specific inductive capacity.) A measure of that property of a medium by virtue of which it modifies the mutual interaction of electrified bodies immersed in it or separated by it. Specifically, the factor by which the **electric flux** produced by a given field is increased by the presence of the **dielectric,** or the factor by which the field produced by fixed charges is decreased. If the dielectric constant of a vacuum is taken as a reference standard and assigned the value unity, the constants for several gases and vapors (at less than 3 cycles per second) are: air, 1.000567 (0°C); benzene, 1.0028 (100°C); ethane, 1.0015 (0°C); hydrogen chloride, 1.0046 (0°C); and steam, 1.00785 (at 140°C). (See **permittivity.**)

The dielectric constant of an assembly of molecules, whether gas, liquid, or solid, depends on the **polarizabilities** and the **dipole moments** of the individual molecules. In the absence of permanent dipoles, it is given by the **Clausius-Mosotti equation.** For dipoles of moment μ, it is given by

$$\epsilon = 1 + \frac{4\pi N\mu^2}{3k(T - T_c)}$$

where $T_c = 4\pi N\mu^2/9k$, the temperature of the **"polarization catastrophe."** This should perhaps be corrected by using the **Onsager theory.** The dielectric constant depends on the frequency of the measuring electric field, owing to **relaxation** effects.

The dielectric constant customarily has the same value in all systems of units, being a dimensionless quantity. The specific inductive capacity of empty space is expressed dif-

ferently in the various systems, being unity in the esu system and 8.85×10^{-12} farads per meter in the MKSCb system. See Introduction.

DIELECTRIC CONSTANT, CLAMPED. The **dielectric constant** of a material when placed under mechanical stress so that it may not be distorted by the applied electric field.

DIELECTRIC CONSTANT, RELATION TO INDEX OF REFRACTION. In 1881, J. C. Maxwell derived a relationship between the **dielectric constant** of a substance and its **refractive index** for light of long wavelength. This relationship is

$$D = n_\infty^2.$$

This relationship applies most closely in cases where the substance is nonpolar, and the molecule has no permanent **dipole moment.**

DIELECTRIC DISSIPATION FACTOR. The cotangent of the **dielectric phase angle** of a dielectric material.

DIELECTRIC HEATING. The heating of a **dielectric** material by molecular friction in it as a result of the application of a high-frequency, alternating electric field.

DIELECTRIC HYSTERESIS. An effect in a **dielectric** material analogous to the **hysteresis** found in magnetic materials.

DIELECTRIC, ISOTROPIC. A **dielectric** whose **permittivity** is independent of the direction of the applied field.

DIELECTRIC LOSS. The power loss in a **dielectric** due to **dielectric heating.**

DIELECTRIC PHASE ANGLE. The angular difference in phase between the sinusoidal alternating voltage applied to a dielectric and the component of the resulting alternating current having the same period as the voltage.

DIELECTRIC POWER FACTOR. The cosine of the **dielectric phase angle.**

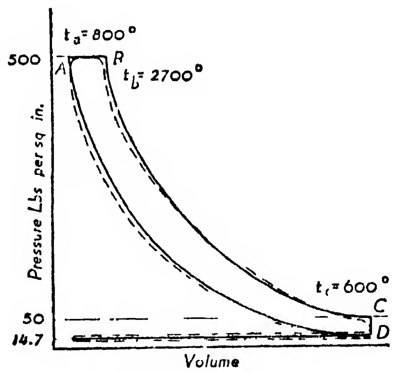
DIELECTRIC RELAXATION. That part of the **dielectric constant** of a solid which depends on the orientation of the **dipole moments** of the molecules is subject to the phenomenon of relaxation. A certain time is required for the assembly of dipoles to come into equilibrium with the applied field. If the field oscillates with a period less than this time, the dipoles cannot follow the motion, and do not contribute to the dielectric constant.

DIELECTRIC STRENGTH. The maximum potential gradient that a material can withstand without rupture.

DIELECTRIC WEDGES. Wedge-shaped pieces of **dielectric** used to match an air-filled **waveguide** to another guide, either partially or completely filled with a dielectric.

DIELECTRIC WIRE. A **dielectric** waveguide.

DIESEL CYCLE. Although modified from the inventor's original conception, the modern Diesel cycle retains the most important feature, namely that of compression of air to the ignition temperature, followed by timed introduction of fuel. This cycle is shown in the accompanying diagram. The solid line



DIESEL CYCLE
Showing the departure of the actual cycle from the theoretical, or air standard cycle

indicates a theoretical cycle, the dotted line shows how a slow-speed actual cycle may depart from the theoretical. Typical temperatures are also indicated. Beginning with point D on the cycle, imagine that a cylinder filled with air is closed at the end by a tightly fitting position. The piston is moved to compress the air without addition or loss of heat through the cylinder walls. As the air is decreased in volume, the pressure rises adiabatically, and it arrives at the condition corresponding to point A. The piston is then reversed in direction, and starts to move so as to increase the volume of the air. The air is very hot due to its **adiabatic** compression.

In fact, it is well above ordinary ignition temperatures of petroleum products. As the piston starts to move, carrying the cycle from point A, fuel is injected or sprayed into the cylinder just rapidly enough so that its combustion will keep the pressure up while the volume is being increased, at least up to point B. At B when the outward stroke is partially completed, the fuel is cut off, and the products of combustion expand adiabatically from B to C, giving work to the piston as they do. At C the exhaust valve opens, and the pressure drops to D. The line extending horizontally from D represents the theoretical exhaust and suction stroke. Adiabatic expansion and compression are not possible in a cylinder which must be well cooled in order to maintain a lubricating oil film. Therefore an actual cycle will not be expected to follow the adiabatic. Another difference between actual and theoretical cases is the composition of the gas within the cylinder. Theoretical studies are made assuming pure air in the cylinder. Actually there is a little burned gas present during the compression, and a great deal of it during the expansion strokes. However, by assuming no friction loss, adiabatic compression and expansion, and air, only, in the cylinder, an expression may be derived for the efficiency of the cycle $ABCD$. (See **air standard efficiency**.)

DIESSELHORST DIFFERENCE POTENTIOMETER. See **potentiometer, Diesselhorst difference**.

DIETERICI EQUATION. A form of the **equation of state,** relating pressure, volume, and temperature of gas, and the gas constant. The Dieterici equation applies a correction to the **van der Waals equation** to allow for variation in density throughout a gas, due to the higher potential energies of molecules on or near the boundaries. One form of this equation is

$$P = \frac{RT}{V - b} e^{-a/RTV}$$

in which P is the pressure of the gas, T is the absolute temperature, V is the volume, R is the gas constant, e is the natural log base $2.718\cdots$, and a and b are constants.

DIFFERENCE AMPLIFIER. An **amplifier** having two inputs, and whose output is a function of their difference.

DIFFERENCE BAND. A spectral band (see **spectrum, band**) in which the initial state of the molecule is not the vibrationless ground state.

DIFFERENCE, CENTRAL. If h is the interval between equally spaced values of the **argument** in a **difference table** constructed from $y = f(x)$, it is convenient to define

$$\delta f(x) = f\left(x + \frac{h}{2}\right) - f\left(x - \frac{h}{2}\right);$$

$$\mu f(x) = \tfrac{1}{2}\delta f(x).$$

A central difference, formed by the first of these operators, is related to a **finite difference** by the equation

$$\delta^m y_{n/2} = \Delta^m y_{(n-m)/2}$$

where m and n are integers, both even or both odd. These quantities are used near the middle of a difference table, as in **Bessel's** and **Stirling's formulas** for **interpolation.**

DIFFERENCE DETECTOR. A circuit whose output is a representation of the differences of the **peak amplitudes** or areas of the input **waveforms.** The input waveforms need not occur simultaneously.

DIFFERENCE, DIVIDED. If y_0, y_1, y_2, $\cdots$ are values of $y = f(x)$, corresponding to x_0, x_1, x_2, $\cdots$, not necessarily evenly spaced, then

$$[x_i x_j] = \frac{y_i - y_j}{x_i - x_j}$$

is a first-order **divided difference** of $f(x)$. Second-order differences, third-order differences, etc., are defined in a similar way, thus the nth order divided difference is

$$[x_0 x_1 \cdots x_n] = \frac{[x_0 x_1 \cdots x_{n-1}] - [x_1 x_2 \cdots x_n]}{x_0 - x_n}.$$

These quantities are used for **interpolation of** tabulated functions when the given data are unequally spaced.

DIFFERENCE, FINITE. Let y_0, y_1, y_2, $\cdots$ be values of $y = f(x)$ and let corresponding values of the independent variable, x_0, x_1, x_2, $\cdots$, be equally spaced so that $x_n - x_0 = nh$, where n is an integer. First differences are then defined as

$$\Delta y_0 = y_1 - y_2; \quad \Delta y_1 = y_2 - y_1;$$
$$\Delta y_{n-1} = y_n - y_{n-1}.$$

Second differences, third differences, etc., are defined in a similar way and the $(n + 1)$th order differences are

$$\Delta^{n+1} y_0 = \Delta^n y_1 - \Delta^n y_0;$$
$$\Delta^{n+1} y_1 = \Delta^n y_2 - \Delta^n y_1; \quad \cdots$$

By successive substitution, it is found that

$$\Delta^n y_k = \sum_{r=0}^{n} (-1)^r \binom{n}{k} y_{k+n-r}.$$

Quantities of this kind are called **diagonal or forward differences.** They are generally displayed in a **difference table** and used for **interpolation.** See also **difference, central; divided; horizontal.**

DIFFERENCE, HORIZONTAL. If $\Delta^m y_k$ is a finite difference of mth order, or diagonal difference,

$$\Delta^m y_k = \Delta^{m-1} y_{k+1} - \Delta^{m-1} y_k$$

then a **horizontal difference** is defined as

$$\Delta_m y_{k+m} = \Delta^m y_k$$

or

$$\Delta_m y_n = \Delta^m y_{n-m}.$$

Interpolation formulas expressed in terms of horizontal differences are sometimes simpler than those using diagonal differences. (See **difference, finite.**)

DIFFERENCE LIMEN (DIFFERENTIAL THRESHOLD) (JUST NOTICEABLE DIFFERENCE). The increment in a stimulus which is just detected in a specified fraction of the trials. The relative difference limen is the ratio of the difference limen to the absolute magnitude of the stimulus to which it is related. According to the Weber law, the relative difference limen is a constant. This law is only approximately true.

DIFFERENCE NUMBER. The same as **neutron excess.**

DIFFERENCE TABLE. A tabular arrangement of $y_0, y_1, y_2, \cdots$, a set of values of $y = f(x)$, together with corresponding values of the **argument,** $x_0, x_1, x_2, \cdots$ and the **finite differences.** Such a table is generally used for **interpolation.** Both diagonal and horizontal arrangements of the differences are used.

DIFFERENTIAL. If the variable y depends on the single independent variable x, so that $y = f(x)$, their **differentials** are designated by dy and dx. If $dx \neq 0$, the ratio of the differentials is the derivative of y with respect to x

$$\frac{dy}{dx} = \frac{f'(x)dx}{dx} = f'(x).$$

(See also **Pfaff expression; differential, total.**)

DIFFERENTIAL, EXACT. See **differential, total.**

DIFFERENTIAL EQUATION. An equation involving **derivatives** or **differentials** of an unknown function. When **partial derivatives** occur the equation is a **partial differential** one, otherwise an **ordinary** one. The **order** of the highest derivative occurring is the order of the equation and the highest power of the function or its derivative is the **degree.** Equations of the first degree are called **linear,** others are **non-linear.** Further classifications include **exact, total, systems, homogeneous, inhomogeneous,** and **singular.** Solving the equation means to find a function which satisfies the equation. Solutions are **particular, general,** or **singular. Boundary conditions** are normally specified along with the equation and serve to specify the particular solution. Equations frequently occurring are those of **Bernoulli, Euler, Clairaut, Bessel, Fourier, Laplace, Legendre, Laguerre, Poisson,** and **Weber,** as well as the **hypergeometric** and **Sturm-Liouville** forms.

DIFFERENTIAL EQUATION, EXACT. A **total differential equation** obtained by differentiating some function $\phi(x,y) = C$, hence its form is

$$P(x,y)dx + Q(x,y)dy = 0$$

where $P = \partial\phi/\partial x$; $Q = \partial\phi/\partial y$ and its left-hand side is thus an **exact differential.** The necessary and sufficient condition for exactness is $\partial P/\partial y = \partial Q/\partial x$, which is a special case of the **Cauchy-Riemann equations. Integrating factors** may always be found for inexact equations in two variables and an infinite number of them will exist. The exact equation, or one which has been made exact by such a factor, is integrable by **quadrature.**

DIFFERENTIAL EQUATION, HOMOGENEOUS. The term is used with two meanings: (1) A **first-order equation,** $Adx + Bdy = 0$ if $A(x,y)$ and $B(x,y)$ are **homogeneous functions** of the same **degree;** (2) a **differential equation,** $f(x,y,y',y'',\cdots) = 0$ is homogeneous if f is a homogeneous function of y and all of its derivaties. (See **equation, linear.**)

DIFFERENTIAL EQUATION, LINEAR. One of the first **degree.** When written with integral exponents, it is an equation in which the unknown function and its derivatives occur only to the first power.

DIFFERENTIAL EQUATION, SOLUTION OF. An **ordinary differential equation** has as its **general solution** an expression containing a number of arbitrary constants equal to the order of the equation. Imposition of **boundary conditions** specifies the values of the constants and yields a **particular solution.** Certain special solutions, called **singular solutions,** occasionally occur which cannot be obtained from the general solution. (See also **primitive.**)

DIFFERENTIAL EQUATION SYSTEM. Each equation of the system contains one independent variable and n dependent variables. The system is composed of n such differential equations.

DIFFERENTIAL EQUATION, TOTAL. An equation of the form

$$Pdx + Qdy + Rdz = 0$$

where P, Q, R are functions of the independent variables x,y,z. It may have a general solution $\phi(x,y,z) = C$, where C is a constant, for total differentiation of this result gives

$$\frac{\partial\phi}{\partial x}dx + \frac{\partial\phi}{\partial y}dy + \frac{\partial\phi}{\partial z}dz = 0$$

and if the partial derivatives have a common factor μ ($\mu = 1$ is included), called an **integrating factor,** so that

$$\mu P = \partial\phi/\partial x; \quad \mu Q = \partial\phi/\partial y; \quad \mu R = \partial\phi/\partial z$$

then a total differential equation of the form indicated has been obtained. However, it does not follow that every total differential equation has such a solution for there may be no integrating factor. A necessary and sufficient condition for its existence, and hence for a solution of the form assumed, is

$$\begin{vmatrix} P & Q & R \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ P & Q & R \end{vmatrix} = 0.$$

This is the condition for integrability and, if the determinant does not vanish, the total differential equation is said to be non-integrable, the equation then being known as **Pfaff's problem.**

Total differential equations in more than three variables may also occur. When there are only two, they are always integrable. (See **differential equation, exact.**)

DIFFERENTIAL GAIN (IN TELEVISION). In a video transmission system, the difference in the **gain** of the system **in decibels** for a small high-frequency sinewave signal at two stated levels (see **level (2)**) of a low-frequency signal on which it is superimposed The two frequencies should be specified

DIFFERENTIAL PHASE (IN TELEVISION). In a video transmission system, the difference in phase shift through the system for a small high-frequency sinewave signal at two stated levels (see **level (2)**) of a low-frequency signal on which it is superimposed. The two frequencies should be specified.

DIFFERENTIAL PHASE SECTION. A **waveguide filter** which introduces a phase difference between individual components being transmitted.

DIFFERENTIAL THERMOMETER. See **vapor pressure, methods of measurement.**

DIFFERENTIAL THRESHOLD. See **difference limen.**

DIFFERENTIAL, TOTAL. Given a function of several independent variables, the **total** or **complete differential** is a sum of terms containing **partial derivatives** as coefficients

$$d\phi(x,y,z,\cdots) = \frac{\partial\phi}{\partial x}dx + \frac{\partial\phi}{\partial y}dy + \frac{\partial\phi}{\partial z}dz + \cdots.$$

To emphasize the fact that the **function** $d\phi$ has been obtained by differentiation, it is also called an **exact** or **perfect differential.** (See also **differential equation, exact or total.**)

DIFFERENTIATING CIRCUIT. A grouping of components that possess the ability to produce an output voltage proportional to the rate of change of the input signal.

DIFFERENTIATING NETWORK. See **network, differentiating.**

DIFFERENTIATION. The process of finding the **derivative** of a function. If there are several independent variables **partial derivatives** result. (See also **graphical differentiation; numerical differentiation.**)

DIFFERENTIATION, GRAPHICAL. See **graphical differentiation.**

DIFFERENTIATION, NUMERICAL. See **numerical differentiation.**

DIFFERENTIATION UNDER THE INTEGRAL SIGN. For the **differentiation** of a **definite integral** of a function $f(x,m)$ containing a parameter m, when the limits of the integral are constants a and b,

$$\frac{d}{dm}\int_a^b f(x,m)dx = \int_a^b \frac{\partial f}{\partial m}\,dx$$

and when the limits of the integral are u and v, functions of m:

$$\frac{d}{dm}\int_u^v f(x,m)dx = \int_u^v \frac{\partial f}{\partial m}\,dx + f(v,m)\frac{dv}{dm} - f(u,m)\frac{du}{dm}.$$

DIFFERENTIATOR. A device, usually of the **analog** type, whose output is proportional to the derivative of an input signal.

DIFFRACTED WAVE. See **wave, diffracted.**

DIFFRACTION. (1) For the use of this term in acoustics, see **wave, diffracted.** (2) In optics, the interference pattern resulting from the rays through different parts of an opening, or from different points around an opaque object as they unite at each point.

Fresnel Diffraction. The intensity at any point is the resultant of disturbances coming directly to that point from all parts of the exposed wave front. In general, the wave front is spherical or circular, resulting from a source at finite distance, and the point of observation is also at finite distance.

Fraunhofer Diffraction. A lens is placed beyond the aperture or obstacle, and the diffraction pattern is examined in the plane where a sharp image of the source would be formed in the absence of the aperture or obstacle. In general, Fraunhofer diffraction is a phenomenon observed at effectively infinite distance from the aperture or the obstacle, and the source is also effectively at infinite distance.

For a single slit of width a and light of wavelength λ, falling on the slit at normal incidence, the intensity of light at an angle θ from the normal to the slit is given by

$$I = R_0^2\,\frac{\sin^2\left(\dfrac{\pi a \sin\theta}{\lambda}\right)}{\left(\dfrac{\pi a \sin\theta}{\lambda}\right)^2}.$$

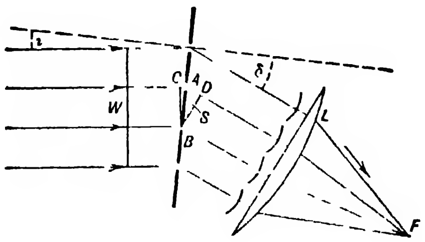
Other diffraction patterns have been computed, but are more complicated (See Robertson, *Introduction to Optics*, 4th ed., Chapters X and XI.)

DIFFRACTION, CIRCULAR APERTURE. The diffraction pattern of a small circular opening is circular, the fringes being farther apart the smaller the opening. The limit of resolution of a circular opening is $\phi = 1.22\lambda/a$ where a is the diameter of the opening. This dependence of resolving power on aperture is one of the reasons for making telescopes with as large an aperture is practicable. (The other reason for large aperture is to increase the light-gathering power of the instrument.)

DIFFRACTION GRATING. A series of very fine, closely spaced parallel slits, or of very narrow, parallel reflecting surfaces, which, when light is incident upon it at a definite angle, produces a succession of spectra. The complete optical theory is somewhat complicated, but the action of a plane transmission grating may be explained approximately as follows.

A plane, monochromatic light wave W, incident at angle i (see figure), reaches the slits at different times. A lens L receives the waves emerging from any two adjacent slits, A and B (among many others), after they have traveled paths differing by $CA + AD$; that is, by $S \sin i + S \sin \delta$, in which $S = AB$. If the lens is so placed that this path difference is a whole number of wavelengths, $n\lambda$, the

successive wave-trains will reach it in the same phase, so that when they are brought to the focus F, they will be in synchronism and



Diffraction by a plane grating

will produce a bright image of the distant source. Therefore any angle δ for which this result is possible is subject to the condition

$$S \sin i + S \sin \delta = n\lambda,$$

or

$$\sin \delta = \frac{n\lambda}{S} - \sin i.$$

Bright images will be produced for those angles δ which correspond to $n = 1, 2, 3, 4, \cdots$; the numbers denote the "orders" of the images. It is easily shown that for any order the total deviation $(i + \delta)$ is least when $\delta = i$ and therefore when

$$\sin \delta = \frac{n\lambda}{2S}.$$

If the incident light is composed of various wavelengths, the corresponding images of any order will appear at different points, since δ varies with λ; and the result is a **spectrum.** In short, the grating acts as a **dispersion** piece, and as such is of great value in **spectroscopes and spectrographs.**

DIFFRACTION, HALF-PERIOD ELEMENTS OR ZONES. In Fresnel **diffraction,** the intensity of radiation meeting any point from a spherical wave front may be determined by dividing the wave front into zones such that radiation from one zone will reach the given point one half-period out of phase with the adjacent zones. The resultant amplitude at the given point can be shown to be equal to half the sum of the amplitudes from the first and last zone. (See **zone plate.** See Robertson, *Introduction to Optics,* 4th ed., Chapter X.)

DIFFRACTION INSTRUMENT. Any device employed for studying the structure of matter or the properties of radiation by means of the diffraction of waves; for example, x-rays, electrons, or neutrons.

DIFFRACTION SYMMETRY. Certain types of **symmetry** of the crystal lattice lead to the systematic extinction of certain beams in **x-ray diffraction.** The observation of such effects often allows the **space group** of the **crystal structure** to be inferred (same as **space group extinction**).

DIFFUSE REFLECTION, REFRACTION OR TRANSMISSION. Reflection, refraction, or **transmission** in all directions, not in any sharply defined path.

DIFFUSE SERIES. See **series in line spectra.**

DIFFUSE SOUND. See **sound, diffuse.**

DIFFUSE TRANSMISSION DENSITY. See **transmission density, diffuse.**

DIFFUSE TRANSMITTANCE. See **transmittance.**

DIFFUSER. (1) Diverging duct designed to reduce the velocity of a stream of fluid without loss of total head and so to recover pressure head as the kinetic head is reduced. Successful operation of a diffuser depends on having both a suitable shape of duct and a well-behaved flow at the entrance. (2) A device, such as a silk screen or a ground glass plate, which converts a narrow pencil of radiant energy into a much broader pencil.

DIFFUSION. (1) The process by which molecules intermingle as a result of their random thermal motion. In gases and in liquids in the neighborhood of the **critical point,** the molecular motion resembles a "random walk," and the diffusion coefficient is of order $\frac{1}{3}\bar{c}\lambda$, where $\bar{c}$ is the mean **thermal** velocity of a molecule and λ is the mean free path of a free molecule. If the liquid is more highly condensed, diffusion depends on thermally induced movements from one stable position in the local lattice to another one, as in diffusion of solids. Diffusion in liquids is extremely slow, but it may be accelerated by inducing a turbulent flow which mingles the separate components intimately and allows molecular diffusion to take place down greatly increased local intensity gradients.

(2) The passage of particles through matter in such circumstances that the probability of scattering is large compared with that of leakage or absorption. It is often limited to phenomena described by a member of the class of differential equations known as diffusion equations.

DIFFUSION ANALYSIS. The determination of the relative size or molecular weight of particles by comparing their diffusion rates, or by separating them by differential diffusion methods.

DIFFUSION BARRIER. A porous partition, such as a thin sheet of silver-zinc alloy etched by hydrochloric acid, which contains submicroscopic holes through which material transfer takes place by diffusion rather than by ordinary hydrodynamic flow.

DIFFUSION COEFFICIENT. The constant of proportionality in **Fick's law,** which states that the current is proportional to the negative gradient of the flux or of the density. The corresponding proportionality constants are the diffusion coefficient of flux and of density.

DIFFUSION COLUMN. A vertical tube, within which a radial temperature gradient is maintained. As a result of convection, the relative concentrations of heavy and light molecules are different at the upper and lower ends of the column. Used in the separation of isotopes.

DIFFUSION CONSTANT (IN A HOMOGENEOUS SEMICONDUCTOR). The quotient of **diffusion current density** by the charge **carrier** concentration gradient It is equal to the product of the **drift mobility** and the average thermal energy per unit charge of carriers.

DIFFUSION CURRENT. The limiting current which is reached by electrolytic **migration** of the ions in a solution under the application of a **potential difference** to the electrodes. As the potential difference is increased the ion current to the electrodes increases rapidly at first but soon reaches a limiting value (the diffusion current value) as the potential difference is increased. If the potential difference is increased still further, a point is ultimately reached at which a new ion species begins to discharge.

The current limit is set by the rate of diffusion (of the ion being discharged) through the depleted layer surrounding the electrode. This diffusion rate is proportional to the ion concentration. For application of this effect see **polarography.**

DIFFUSION EQUATION. See **diffusion, Fick law.**

DIFFUSION EQUATION, GENERAL. In nuclear **reactor** theory, a generalization of the thermal neutron **diffusion equation,** in which the density of thermal neutrons may change with time, and in which scattering, leakage, and absorption are taken into account.

DIFFUSION EQUATION, NONEQUILIBRIUM. In nuclear **reactor** theory, the **diffusion equation** for thermal neutrons modified to include a source term which describes the increase in thermal neutron density due to the slowing down of fission neutrons The equation can be written as

$$D\nabla^2\phi - \Sigma_a\phi + S = \frac{\partial n}{\partial t} = \frac{1}{v}\frac{\partial \phi}{\partial t}$$

where $\phi = nv$ is the neutron flux (n = number of neutrons per unit volume, v = velocity), Σ_a is the macroscopic absorption cross section, and S is the source term.

This equation applies only to monoenergetic neutrons, and only at distances greater than 2 or 3 mean free paths from strong sources.

DIFFUSION, EYRING TREATMENT OF. See **Eyring treatment of diffusion.**

DIFFUSION, FICK LAW. The rate of diffusion of particles across a given area is proportional in amount and opposite in sign to the concentration gradient. This relation is expressed by the equation

$$\mathbf{Q} = -D\,\mathbf{grad}\,c$$

where **Q** is the vector rate of diffusion across unit area in unit time, c is the concentration, D is the diffusion coefficient. Making use of the principle of conservation of mass, this equation may be written

$$\nabla^2 c = -\frac{1}{D}\frac{\partial c}{\partial t}.$$

DIFFUSION IN SOLIDS. A phenomenon which occurs rather slowly, but can be observed. Three basic processes may be responsible: (a) Direct exchange of atoms on neighboring sites. (b) Migration of **interstitial atoms.** (c) Diffusion of **vacancies.** The first process requires very large energy. The energy to make an interstitial migration is rather large, but many atoms migrate easily. Vacancies are fairly readily formed, and diffuse fairly easily. From the **Kirkendall effect** it appears that (b) and (c) are the usual processes. The diffusion coefficient is related to the **ionic mobility** by the **Einstein relation.**

DIFFUSION INDICATRIX. A graph in polar coordinates showing the intensity of **reflection** of a given element of an illuminated diffusing surface as viewed from various directions in a plane perpendicular to the element.

DIFFUSION LAYER. A layer of solution, actually a double layer, that is in immediate contact with an **electrode** during **electrolysis.**

DIFFUSION LENGTH. The mean distance traveled by a diffusing particle from the point of its formation to the point at which it is absorbed (1) In nuclear **reactor** theory, the particle is a **neutron.** (2) In a homogeneous **semiconductor,** the particle is a minority carrier. (See **carrier, minority.**)

DIFFUSION OF GASES. Drift of the molecules of a gas under a concentration gradient (ordinary diffusion) or temperature gradient (thermal diffusion) For different gases, the rate of diffusion under a concentration gradient is inversely proportional to the square root of the density (**Graham Law**).

DIFFUSION POLARIZATION. See **polarization, diffusion.**

DIFFUSION POTENTIAL. When liquid junctions exist where two **electrolytic solutions** are in contact, as in the case of two solutions of different concentrations of the same electrolyte, diffusion of ions occurs between the solutions, and the differences in rates of diffusion of different ions set up an electrical double layer, having a difference of potential, known as the diffusion potential or liquid junction potential.

DIFFUSION PUMP BACK-STREAMING. The streaming of mercury vapor towards the high-vacuum side of a diffusion pump. (See **pump, diffusion.**)

DIFFUSION PUMP, BOTTLE. A variation of the Gaede diffusion pump (see **diffusion pump, Gaede**), in which the mercury vapor is condensed on the upper parts of the bottle and in the high-vacuum and fore-vacuum tubes, returned to the boiler, and used over and over again.

DIFFUSION PUMP, CRAWFORD DIVERGENT NOZZLE. A diffusion pump (see **pump, diffusion**), in which the "back streaming" (flow of vapor toward the high vacuum) is reduced by the use of a specially-designed nozzle

DIFFUSION PUMP, GAEDE. The earliest form of diffusion pump (1915) (see **pump, diffusion**), in which mercury vapor is made to pass along a tube, with the vessel to be evacuated connected to a side tube Air from the side tube is entrained by the mercury vapor and is swept away, while any mercury vapor that passes into the pumping tube is condensed by a cold trap before it can reach the vessel to be evacuated.

DIFFUSION PUMP, LANGMUIR. A form of diffusion pump (see **pump, diffusion**), in which a nozzle is incorporated for the purpose of giving the mercury vapor in the pumping aperture a general direction away from the high-vacuum side of the pump.

DIFFUSION PUMP, SIMPLE OIL. A diffusion pump (see **pump, diffusion**) using oil instead of mercury vapor, but otherwise having no features of design radically different from the mercury vapor pumps. The oil diffusion pumps are used mainly in cases where the requirements of ultimate vacuum are not particularly exacting. For moderate vacuum, an oil pump may often be operated without a refrigerant, which is necessary with a mercury pump to condense vapor which may diffuse into the high vacuum connections.

DIFFUSION-PUMP STREAMING VELOCITY. The velocity with which vapor finally issues from the mouth of the nozzle of a diffusion pump. (See **pump, diffusion.**)

DIFFUSION-PUMP STREAMING VELOCITY, MAXIMUM. The maximum value that the streaming velocity can achieve in a process in which the vapor is accelerated by its own expansion, as in the case of a divergent nozzle diffusion pump, is the velocity of sound in the vapor at the prevailing temperature.

DIFFUSION PUMP, THEORY. The main results of the theory of diffusion pumps (see **pump, diffusion**) are:

(1) The mean free paths of vapor and gas molecules should be of the order of magnitude of the dimension of the pumping aperture.

(2) When once a gas molecule has reached a point well down in the body of the vapor stream, there is practically no possibility of its ever returning to the high-vacuum side of the pump.

(3) Pumping speed should be inversely proportional to the square root of the molecular weight of the gas being pumped. This is not always experimentally observed, since there are effects due to heater power, etc.

DIFFUSION TIME OR LIFETIME, AVERAGE. The average time spent by a diffusing particle between the moment of its formation and the moment of its absorption. In nuclear **reactor** theory the particle is a thermal neutron and its diffusion time in most **moderators** is a fraction of a second.

DIFFUSIVE SUBSTANCES. Substances that readily dialyze through colloidal septa, viz., crystalloids.

DIFFUSIVITY. Diffusion coefficient; a constant, relating the rate of change of **concentration** of material at any point in space to the **gradient** of the concentration at that point along a given direction. (See **diffusion, Fick law.**)

DIG-IN ANGLE. In disk recording, the angle (less than 90°) between the cutting stylus and the record when the stylus is positioned so that it tends to dig into the record. It is the opposite of **drag angle.**

DIGIT. One of a definite set of characters which are used as coefficients of powers of the **radix** in the positional **notation** of numbers.

DIGIT(S), SIGNIFICANT. (1) In computer work, the digits of a number can be ordered according to their significance; the significance of a digit is greater when it occupies a column corresponding to a higher power of the **radix.** The significant digits of a number are a set of digits from consecutive columns, beginning with the most significant digit different from zero, and ending with the least significant digit whose value is known or assumed to be relevant. (2) In the expression of the magnitude of a physical quantity, the significant digits are those which are believed to be closer to the true value than any other digit would be. Thus the quantity 1830 ± 2 has four significant digits, while the number 1830 ± 20 has only three and is preferably written as 1.83×10^3.

DIGITAL COMPUTER. A **computer** in which information, numerical or otherwise, is represented by means of combinations of characters in such a way that the number of distinguishable combinations is much greater than the number of distinguishable characters. Thus, a digital computer is one which makes explicit use of a **language.**

DIHEPTAL BASE. A **tube base** having 14 pins.

DILATANCY. The property of certain **colloidal solutions** of becoming solid, or setting, under pressure. Also known as "inverse plasticity" since there is an increase in the resistance to deformation with increase in the rate of shear.

DILATATION. The increase of volume per unit volume of a continuous material.

DILATION. The fractional increment in volume caused by a deformation.

DILATION NUMBER. Ratio of the volume of a liquid to the volume of a solid of the same composition at the same temperature.

DILATOMETER. An instrument used to measure small increments in the volume of liquids, as a solid phase separates.

DILUTION. (1) The act of increasing the proportion of solvent to solute in any solution, e.g., by the addition of the same or another (miscible) solvent. (2) Improperly used in the same sense as concentration, to express the amount of solute per unit volume of solution.

DILUTION LAW (OSTWALD). For sufficiently dilute solutions, the **activity coeffi-**

cients of the ions and neutral electrolyte are approximately unity, so that the **dissociation constant** is approximated by $\alpha^2c/(1-\alpha)$ where α is the degree of dissociation, and c the total electrolyte concentration (in moles per liter).

DIMENSION. The dimensions of a physical quantity are an indication of the nature of the quantity, any two quantities with the same dimensions being mutually convertible and being expressible in the same units. Dimensions are frequently expressed in terms of a few fundamental units, such as those of length, mass and time. See Introduction.

DIMENSIONAL ANALYSIS. Since the quantities represented by the two sides of an equation must have the same dimensions, it is often possible to arrive at the form of an equation connecting physical quantities by a consideration only of the dimensions of the quantities involved, without a detailed theory and without consideration of magnitudes. The equations obtained in this way may be in error by a multiplying constant, which can often be determined empirically. Dimensional analysis has been particularly useful in the development of aerodynamics and hydrodynamics.

DINA. Abbreviation for digital network analyzer.

DINEUTRON. A combination of two **neutrons**, considered to have a transitory existence in **nuclear reactions** produced by **tritons** which result in the formation of a proton and nucleus having the same atomic number as, but a mass number two units greater than, the target nucleus.

DIODE. A two-electrode device, having an anode and a cathode, which has marked unidirectional characteristics. (See **tube, electron; diode, crystal; diode, junction; diode, semiconductor.**)

DIODE, CATCHING. See **catching diode.**

DIODE CHARACTERISTIC (OF A MULTIELECTRODE TUBE). The composite electrode characteristic taken with all electrodes, except the cathode, connected together.

DIODE, CRYSTAL. A diode consisting of a **semiconducting material,** such as a germanium or silicon, as one electrode, and a fine wire "whisker" resting on the **semiconductor** as the other electrode. Because of its low capacitance, the device finds considerable application as a **rectifier** or **detector** of **microwave** frequencies.

DIODE DEMODULATOR. See **demodulator, diode.**

DIODE, DOUBLE. See **duodiode.**

DIODE, DOUBLE-BASE. A **semiconductor diode** in which a **potential gradient** is produced across the base region by the application of a voltage between two electrodes at either end of the base. The correct polarity and magnitude of this voltage causes the diode to exhibit a controllable, negative resistance between one of the base electrodes and the anode.

DIODE, EQUIVALENT. The imaginary **diode** consisting of the cathode of a triode or multigrid tube, and a **virtual anode** to which is applied a composite controlling voltage such that the cathode current is the same as in the triode or multigrid tube.

DIODE, JUNCTION. A semiconductor diode whose nonsymmetrical volt-ampere characteristics are manifested as the result of the **junction** found between ***n*-type** and ***p*-type** semiconductor materials. This junction may be either diffused, grown, or alloyed.

DIODE, SEMICONDUCTOR. A two-electrode semiconductor device having an asymmetrical voltage-current characteristic

DIOPHANTINE EQUATION. An **indeterminate equation** with integers as coefficients and solutions also required to be integers.

DIOPTER (A UNIT). The power of a **lens** expressed as the reciprocal of its **focal length** measured in meters.

DIOPTRIC SYSTEM. If an optical system is **convergent,** it is called dioptric if both **focal lengths** are positive. If an optical system is **divergent,** it is called dioptric if both focal lengths are negative.

DIOTRON. A computer circuit **utilizing an** emission-limited **diode.**

DIP-CIRCLE. See **dip-needle.**

DIP NEEDLE. More properly called an inclinometer. The instrument consists essentially of a magnetic needle poised to swing on a horizontal pivot and thus to indicate the "dip" or inclination of the earth's magnetic field. The zero diameter of the vertical graduated circle should be carefully leveled and

Dip needle or magnetic inclinometer

adjusted to the magnetic meridian. In order to correct for errors of level, balance, magnetization, and eccentricity, the circle should be reversed north to south, the needle axis should be reversed in its bearings, the magnetization should be reversed, and for each of these positions both ends of the needle should be read on the circle. A complete observation is thus the mean of 16 circle readings.

DIPHONIA, DYNAMIC. The phenomenon wherein slight movements of a listener's head bring about abrupt shifts in apparent **sound source** positions, as when stereo-loudspeakers are not properly phased and the listener is positioned between loudspeaker **sound fields.**

DIPLEX RADIO TRANSMISSION. See **transmission, diplex radio.**

DIPOLE. (1) A combination of two electrically or magnetically charged particles of opposite sign which are separated by a very small distance. (2) Any system of charges, such as a circulating current, which has the properties that: (a) no forces act on it in a uniform field; (b) a torque proportional to sin θ, where θ is the angle between the dipole axis and a uniform field, does act on it; (c) it produces a potential which is proportional to the inverse square of the distance from it.

DIPOLE ANTENNA. See **antenna, dipole.**

DIPOLE, ELECTRIC. See **electric dipole.**

DIPOLE, FOLDED. See **antenna, folded-dipole.**

DIPOLE MOMENT. A mathematical entity: the product of one of the charges of a dipole unit by the distance separating the two dipolar charges. In terms of the definition of a dipole (2), the dipole moment **p** is related to the torque **T**, and the field strength **E** (or **B**) through the equation:

$$\mathbf{T} = \mathbf{p} \times \mathbf{E}.$$

DIPOLE MOMENT, INDUCED. A **dipole moment** induced in a system (e g., in an atom or molecule) because it is brought into an electric or magnetic field.

DIPOLE MOMENT, MOLECULAR. It is found from measurements of **dielectric constant** (i.e., by its temperature dependence, as in the **Debye equation for total polarization**) that certain molecules have permanent dipole moments. These moments are associated with transfer of charge within the molecule, and provide valuable information as to the molecular structure.

DIPOLE ORIENTATION. The effect by which the free rotation of the molecules in a solid may be hindered, so that their **dipole moments** may only take on certain discrete orientations. This may have a marked effect on the **dielectric constant.**

DIPOLE RADIATION, ELECTRIC. Radiation which occurs as the result of the time variation of an electric **dipole moment.**

DIPOLE RADIATION, MAGNETIC. Radiation which occurs as the result of a variable magnetic **dipole moment.** If the two magnetic moments due to the vectors L and S do not compensate, a variable magnetic dipole results which may act as a source of radiation.

DIPOLE RELAXATION. See **dielectric relaxation.**

DIRAC CLASSICAL ELECTRON THEORY. Method of defining the force on an electron by subtracting the proper field from the external field, the proper field being the average of the **retarded** and **advanced fields,** and the external field being one half of the difference of these fields. Yields the radiation-damping term in the equation of motion, but leads also to solutions in which the electron

would be accelerated even in the absence of an external field.

DIRAC DELTA FUNCTION. The **improper function** $\delta(x - x_0)$, so defined that

$$\int f(x)\delta(x - x_0)dx = f(x_0)$$

for any $f(x)$. It may be approximated by

$$\delta x = \lim_{h \to 0} \begin{cases} 0; & x < -h/2 \\ 1/h; & -h/2 < x < h/2. \\ 0; & x > h/2. \end{cases}$$

The function $u(x) = \int_{-\infty}^{x} \delta(x)dx = \begin{cases} 0; & x < 0 \\ 1; & x > 0 \end{cases}$

is known as the **unit step function.**

The **Dirac delta function** is also known simply as the **delta function,** but see also **Kronecker delta.**

DIRAC ELECTRON THEORY. Relativistic quantum theory of the electron proposed by Dirac in 1927, and especially remarkable for its prediction of the value $e\hbar/2mc$ for the component in a particular direction of the magnetic moment of a **nonrelativistic** electron The theory is based on the Dirac equation

$$\left(\sum_{\mu=1}^{4} \gamma_\mu \frac{\partial}{\partial x_\mu} + \mathcal{K}\right)\psi = \frac{ie}{\hbar c}\sum_{\mu=1}^{4} \gamma_\mu A_\mu \psi$$

($\mathcal{K} = mc/\hbar$) where γ_μ are the **Dirac operators** and ψ is the wave function of an electron under the influence of the electromagnetic potentials A_μ. In the representation in which the γ_μ are 4×4 matrices, ψ consists of four wave functions, and the equation becomes a set of four first order partial differential equations.

The theory, regarded as a classical **field theory,** describes with precision the behavior of an electron in an electromagnetic field (see however, **Lamb shift**). Even in a central electrostatic field the **orbital angular momentum** $\mathbf{l}$ of the electron is not a constant of the motion, but it is found that the total angular momentum $\mathbf{j} = \mathbf{l} + \mathbf{s}$ stays constant, where, for example,

$$s_z = -\frac{i\hbar}{2}\gamma_1\gamma_2 = \frac{\hbar}{2}\sigma_z$$

(σ = **Pauli spin operator**). Thus associated with the electron is an intrinsic spin, a component of which has the eigenvalues $\pm\hbar/2$

In the limit of small velocities, the theory deduces to nonrelativistic **quantum mechanics** with the inclusion of spin, though both within and outside of this limit the electron possesses an intrinsic oscillatory motion (see **zitterbewegung**) of frequency $2E/\hbar$. The latter is demonstrated most easily in the **Heisenberg representation** since even for a free particle the velocity does not commute with the Hamiltonian:

$$H = c\boldsymbol{\alpha}\cdot\mathbf{p} + \beta mc^2$$

and hence the velocity is not a constant of the motion. The momentum of a free particle, however, is a constant

The anticommuting Dirac operators γ_μ ($= -i\beta\boldsymbol{\alpha}, \beta$) have the property that if for a free particle one operates on the Dirac equation with the operator

$$\left(\sum_{\mu=1}^{4} \gamma_\mu \frac{\partial}{\partial x_\mu} - \kappa\right)$$

the resulting equation is the **Klein-Gordon equation** which describes a particle of energy E, momentum p, where

$$E = \pm(p^2c^2 + m^2c^4)^{1/2}.$$

In virtue of this relativistic equation the Dirac theory includes as possible solutions states of negative energy to which a positive energy particle would make a transition under the influence of a perturbation (see **Klein paradox**). It is therefore necessary to suppose that for a vacuum all such states are filled and a free positive energy particle would be prevented by the **Pauli exclusion principle** from making such a transition. A hole in this distribution of negative energy electrons is then interpreted as a positron (see **positron theory**) Although it is not strictly necessary to use the concept of a negative energy sea of electrons, one is forced to the conclusion that the Dirac theory is fundamentally a theory of many real and virtual electron-positron pairs, the creation and annihilation of which may be described by means of **quantized field theory.** This more complete many-particle theory is able to describe **radiative corrections** to the single particle theory (see **quantum electrodynamics**).

DIRAC EQUATION (UNQUANTIZED). The equation

$$\left(\gamma_\mu \frac{\partial}{\partial x_\mu} + \frac{mc}{\hbar}\right)\psi = \frac{ie}{\hbar c}\gamma_\mu A_\mu \psi$$

describing the motion of an electron or positron in an electromagnetic field described by A_μ. Summation over the values $\mu = 1, 2, 3, 4$, is implied. The γ_μ are the Dirac operators, and ψ may be represented by four functions of position and time.

DIRAC $\hbar$. See **h-bar.**

DIRAC OPERATORS. The operators γ_μ $(\mu = 1, 2, 3, 4)$ where $\gamma_\mu\gamma_\nu + \gamma_\nu\gamma_\mu = 2\delta_{\mu\nu}$ The γ_μ are often written thus:

$$\gamma_1 = \rho_2\sigma_x, \quad \gamma_2 = \rho_2\sigma_y, \quad \gamma_3 = \rho_2\sigma_z, \quad \gamma_4 = \rho_3,$$

where σ_x, σ_y and σ_z are the Pauli spin operators, and $\rho_1\rho_2 = i\rho_3$, etc.

DIRECT CURRENT. See **current, direct.**

DIRECT-CURRENT AMPLIFIER. See **amplifier, direct-current.**

DIRECT-CURRENT CIRCUITS. Unidirectional current is produced from batteries, from dynamo machinery equipped with **commutators**, or by means of **rectifiers.** The great disadvantage of d-c is the fact that until recently it has not been commercially expedient to transform it from low voltage to the high voltage necessary for long-distance transmission of electrical power. Difficulties of **commutation** prevent generation at high voltages. Recently the use of electron tubes, such as the **thyratron,** has opened up new transmission possibilities for d-c.

In lighting and heating apparatus there is not much difference between d-c and a-c, but electroplating can be done only with d-c. D-c **motors** are more expensive than a-c of equivalent power rating, but they have better operating characteristics and simpler speed control. Inductance and capacitance are not important factors in d-c transmission

The basis for most d-c circuit calculations is **Ohm's law.** (See also **electric circuits; Kirchhoff laws.**)

DIRECT-CURRENT GENERATOR. The d-c generator is an ordinary dynamo machine having a multiple-coil winding, the ends of the coils of which are connected to a multiple-segment commutator. The armature is usually rotating, and the field stationary. The field sets up magnetic lines of force, which are cut by the conductors on the revolving armature, giving rise to a generated voltage, which is led through the commutator to a unidirectional external circuit. The iron core is built of laminations of iron insulated from each other by mill scale, or lacquer, or japanning, so that eddy currents which can be generated in the iron core, will be a minimum. The common d-c generator is classified on the basis of the connection of the field current circuit to the armature circuit. If the field is so connected that the armature current flows through it, it is known as a series field. In a series machine, all of the armature current flows through the field. This type of generator is sometimes used to supply series street lamp circuits. The more the armature current, the higher the generated voltage in this type of machine. This characteristic serves to overcome the voltage drop in a series light circuit. A shunt-wound generator is a type in which the field winding has a high resistance, and is composed of a large number of coils of fine wire The terminals of the shunt field are connected across the commutator The shunt-wound generator has definitely drooping voltage characteristics, for the current in the field is dependent on the generated voltage in the armature A compound-wound generator, having both a shunt and a series field, partakes of the best features of both of the other types. When the shunt field is connected across the commutator only, the compounding is called short shunt; when the shunt field is connected across the series field and the commutator, it is a long shunt generator.

DIRECT GRID BIAS. See **grid bias, direct.**

DIRECT OR STATIC METHODS FOR VAPOR PRESSURE. (1) For non-metals at pressures between about 1 cm and 100 cm of mercury, and temperatures below room temperature. A vessel containing the solid or liquid is maintained at a constant low temperature, and is connected to a mercury manometer at room temperature, the vapor pressure being measured directly. One use of this method is for permanent gases between freezing-points and boiling-points.

(2) For substances which are liquid at ordinary temperatures (Regnault method). A few drops of the liquid are introduced into the vacuum at the top of an inverted tube containing mercury, which is connected at the bottom to an open reservoir of mercury. The resulting depression in the column gives the vapor pressure.

The top of the tube is kept in a constant-temperature bath, and corrections must be made for the weight of the liquid and the change in surface tension when the liquid is introduced. This method is used in a temperature range from about 0°C to 50°C. The method may be extended to higher pressures by using a thick-walled, inverted tube connected to a closed reservoir to which pressure may be applied, the pressure then being measured by a suitable manometric device.

DIRECT PRODUCT. Given a **group** G' of order m with elements $A_1, A_2, \cdots, A_m$ and a second group G'' of order n with elements $B_1, B_2, \cdots, B_n$ such that every element of G' commutes with every element of G'', then the mn elements A_iB_j form a group $G = G' \times G''$ of order mn and called the **direct product** of G' and G''.

DIRECT RADIATOR LOUDSPEAKER. See **loudspeaker, direct radiator.**

DIRECT-READING POTENTIOMETER. See **potentiometer, direct-reading.**

DIRECT SUM. The irreducible **representations** of a group

$$\Gamma = c_1\Gamma^{(1)} + c_2\Gamma^{(2)} + \cdots.$$

It does not mean that the matrices $\Gamma^{(i)}$ are to be added but simply indicates that the representation Γ has been decomposed into the given irreducible representations and that $\Gamma^{(i)}$ appears in the representation c_i times

DIRECT WAVE. See **wave, direct.**

"DIRECT" X-RAY ANALYSIS, OR HEAVY ATOM METHOD. In some special cases, the **crystal structure** can be found by **X-ray analysis**, where there is a heavy atom at the center of symmetry of the unit cell, outweighing the contributions of the other atoms to the scattering. The **Fourier synthesis** technique may then be applied directly the **phase angles** being then all zero.

DIRECTED COVALENT BOND. Covalent bonding (see **bond, covalent**) occurs as a result of the overlap of **atomic orbitals**, leading to the lowering of the energy by electron exchange (see **exchange energy**) Naturally, the bond formed by a given orbital will tend to lie in the direction in which the orbital is concentrated, so that there may be the maximum degree of overlap. For example, in H_2O the H atoms are bonded by the p orbitals of the O, which are at right angles, and the two OH axes thus also tend to form nearly a right angle.

DIRECTION COSINE. Let a set of **rectangular coordinate** axes in space be chosen and let L be any line in space. Through the origin of the coordinate system draw another line L', parallel to the given line L Let α, β, γ be the angles which L' makes with the X-, Y-, Z-axes, respectively. These angles are the direction angles of the given line and their cosines $\lambda = \cos\alpha$, $\mu = \cos\beta$, $\nu = \cos\gamma$ are the **direction cosines** of the line. When two angles are given, the third can be found, except for sign, by the Pythagorean theorem

$$\lambda^2 + \mu^2 + \nu^2 = 1.$$

DIRECTION FINDER, ADCOCK. A radio direction finder (see **direction finder, radio**) which utilizes special antenna construction to obtain more accurate results by the elimination of polarization errors. (See **antenna, Adcock.**)

DIRECTION FINDER, CATHODE-RAY H.F. A radio direction finder (see **direction finder, radio**) using a cathode-ray presentation to show the bearing of a station whose transmission is being monitored. It is an extremely fast method of bearing determination.

DIRECTION FINDER, RADIO. A sensitive radio receiver used in conjunction with a directional antenna (see **antenna, directional**) which will permit the determination of the direction from which a transmission is being sent

DIRECTION OF POLARIZATION. See **polarization, direction of.**

DIRECTION OF PROPAGATION. At any point in a homogeneous, isotropic medium, the direction of time-average energy-flow. In a uniform **waveguide**, the direction of propagation is often taken along the axis. In the case of a uniform lossless waveguide, the direction of propagation at every point is parallel to the axis, and in the direction of time-average energy-flow.

DIRECTIONAL ANTENNA. See **antenna, directional.**

DIRECTIONAL CORRELATION OF SUCCESSIVE γ-RAYS. When two **γ-rays** are successively emitted from the same nucleus, their directions and planes of polarization are not entirely independent. The directional correlation is experimentally observed as a change in coincidence counting rate as the angle between the lines joining the source with the two **counters** is varied.

DIRECTIONAL COUPLER. See **coupler, directional.**

DIRECTIONAL GAIN. See **directivity index.**

DIRECTIONAL MICROPHONE. See **microphone, directional.**

DIRECTIONAL RESPONSE PATTERN. See **directivity pattern.**

DIRECTIVE GAIN. In a given direction, 4π times the ratio of the **radiation intensity** in that direction to the total power radiated by the antenna.

DIRECTIVE PATTERN. A **radiation pattern.**

DIRECTIVITY. For an **antenna,** the value of the **directive gain** in the direction of its maximum value.

DIRECTIVITY FACTOR. (a) Of a **transducer** used for sound emission, the ratio of the intensity of the radiated sound at a remote point in a **free field** on the principal axis to the average intensity of the sound transmitted through a sphere passing through the remote point and concentric with the transducer. The frequency should be stated. The point of observation must be sufficiently remote from the transducer for spherical divergence to exist. (b) The directivity factor of a transducer used for sound reception is the ratio of the square of the electromotive force produced in response to sound waves arriving in a direction parallel to the principal axis to the mean square of the electromotive force that would be produced if sound waves having the same frequency and mean-square pressure were arriving at the transducer simultaneously from all directions with random phase. The frequency should be stated. For an electroacoustic transducer obeying the **reciprocity theorem,** the directivity factor for sound reception is the same as for sound emission. These definitions may be extended to cover the case of finite frequency bands whose spectra must be specified. Directivity factor in acoustics is equivalent to **directivity** as applied to antennas.

DIRECTIVITY INDEX (DIRECTIONAL GAIN). Of a **transducer,** an expression of the **directivity factor** in decibels, viz., 10 times the logarithm to the base 10 of the directivity factor.

DIRECTIVITY PATTERN (DIRECTIONAL RESPONSE PATTERN) (BEAM PATTERN). Of a **transducer** used for sound emission or reception, a description, often presented graphically, of the **response** of the transducer as a function of the direction of the transmitted or incident sound waves in a specified plane and at a specified frequency. A complete description of the directivity pattern of a transducer would require three-dimensional presentation. The directivity pattern is often shown as the response relative to the maximum response.

DIRECTLY-HEATED CATHODE. See **filament.**

DIRECTOR. In an **antenna array,** a parasitic element placed in front of a **driven element.** Its purpose is to sharpen the **directivity** of the array, and to increase its **gain.**

DIRECTRIX. See **conic section** and **conical surface.**

DIRICHLET BOUNDARY CONDITION. Specification of the value of the solution to a **partial differential equation** along a bounding surface.

DIRICHLET DISCONTINUOUS FACTOR. The **even function** $f(x)$ defined by

$$f(x) = 1; \quad |x| < 1$$
$$f(x) = \tfrac{1}{2}; \quad |x| = 1$$
$$f(x) = 0; \quad |x| > 1.$$

It may be expressed as the **Fourier integral**

$$f(x) = \frac{2}{\pi}\int_0^\infty \cos uxdu \int_0^1 \cos utdt$$
$$= \frac{2}{\pi}\int_0^\infty \frac{\sin u \cos ux}{u}\,du$$

which is generally known as the **Dirichlet discontinuous factor.**

DIRICHLET INTEGRAL. (1) One of the form

$$J_1 = \int_0^a f(x) \frac{\sin kx}{\sin x}\, dx$$

or

$$J_2 = \int_0^a f(x) \frac{\sin kx}{x}\, dx.$$

It is the expression of the partial sum of the **Fourier series** development of $f(x)$. **Convergence** properties of the integral determine the convergence of the Fourier series. (2) Another integral, also known by the name of Dirichlet, occurs in statistics and statistical mechanics It is

$$J = \int \cdots \iint x^{p-1} y^{q-1} z^{t-1} \cdots dx dy dz \cdots$$

in which the variables are given all possible values consistent with the condition that $(x/a)^2 + (y/b)^2 + (z/c)^2 + \cdots$ be not greater than unity The general integral involves **gamma functions.** The special case for n variables with $a = b = c = \cdots = R$ gives

$$\left(\frac{R}{2}\right)^n \frac{\pi^{n/2}}{\Gamma(n/2 + 1)}.$$

which is the volume of a hypersphere with radius R in n-dimensional space

DISCHARGE. (1) The removal of charge from a **capacitor.** (2) The passage of electric current through a gas (3) The volume of fluid passing a particular cross-section of a stream in unit time (4) The process in which a storage battery delivers electrical energy.

DISCHARGE, COFFFICIENT OF. See **coefficient of discharge.**

DISCHARGE, GASEOUS. The gaseous discharge is the basis of operation of many of the electron tubes in common use. If two electrodes have a gas at low pressure between them and a gradually increasing voltage is applied across them, a series of events takes place as the voltage is raised. First a very small current, of the order of microamperes, will flow as the ions and electrons are attracted to the electrodes. These charged particles are present because various cosmic radiations, radioactive radiations, etc., which are always present except in specially shielded enclosures, ionize the gas molecules. As the voltage is raised the current finally begins to increase rapidly because the electrons being attracted towards the positive electrode have gained sufficient energy to ionize atoms of the gas and thus generate more carriers of the current Suddenly the current increases extremely rapidly, and at the same time the voltage across the tube drops. The value of the voltage at which this occurs is the breakdown voltage and the gas has broken into a self-maintaining discharge called a glow. If the current is not limited by circuit resistance it continues to increase, almost instantaneously, while the voltage drops to a low value and the discharge becomes an **arc.** If the circuit has insufficient resistance the current will reach an enormous value with probable damage to the tube and other circuit elements. The glow discharge is characterized by the ability to pass moderate currents at moderate values of voltage, while the arc will pass very large currents at low values of applied voltage

DISCHARGE, SUBMERGED. A discharge of liquid below the free surface of a container as opposed to a free discharge or a surface discharge

DISCHARGE TUBE. (1) A tube biased to **cut-off,** and therefore non-conducting except when triggered by a positive **pulse.** A condenser, connected in the plate circuit of the tube, charges when the tube is non-conducting and discharges when the tube is triggered and forced into conduction. The tube may be either **vacuum** or **gaseous.** (2) Any tube containing a gas or vapor at low pressure and capable of showing a gaseous discharge. (See **discharge, gaseous.**)

DISCONE. See **antenna, biconical.**

DISCONTINUITY. (1) For the meaning of this term in mathematics, see **function, continuous.** (2) The term applied in a special sense by meteorologists to a zone within which there is a comparatively rapid transition of the meteorological elements, particularly the boundary surface separating **air masses** of different temperatures.

DISCONTINUOUS CONTROL CHARACTERISTICS. See **snap action.**

DISCRETE SENTENCE INTELLIGIBILITY. See **intelligibility, discrete sentence.**

DISCRETE WORD INTELLIGIBILITY. See **intelligibility, discrete word.**

DISCRETENESS. Referring to the distribution of allowed values of a physical quantity over a given interval. The distribution is discrete if only a denumerable set of values is permitted. This is the case, for example, with the allowed frequencies of vibration of a finite stretched string.

DISCRIMINANT. A relation between the coefficients of a **polynomial** which is useful in a study of roots and other properties of the function. It is an **invariant** of the function. (See also **quadratic equation** in one or two variables.)

DISCRIMINATION, COLOR. Perception of differences between colors.

DISCRIMINATION INDEX. The ratio of the **luminance** to the differential luminance threshold. (See **threshold, differential luminance.**)

DISCRIMINATOR. (1) A device wherein **amplitude** variations are derived in response to **frequency** or **phase** variations. (2) A circuit used in connection with counters, having the property that only pulses falling between two limits of amplitude (one of which may be 0 or ∞) are recorded.

DISCRIMINATOR CIRCUIT. A frequency or phase **modulation detector** which causes the magnitude and polarity of its output to be determined by the variation of the input phase or frequency.

DISCRIMINATOR, FOSTER-SEELEY. See **Foster-Seeley discriminator.**

DISCRIMINATOR, FREQUENCY. See **demodulator, frequency.**

DISH. Colloquialism for parabolic antenna. (See **antenna, parabolic.**)

DISINTEGRATION. (1) Loss of form or powdering. (2) The passage of a metal into colloidal solution when it is made an electrode under certain conditions. (3) Transformations of radioactive elements are termed disintegrations, when they result from **radioactivity.**

DISINTEGRATION CHAIN. A synonym for **radioactive series.**

DISINTEGRATION CONSTANT. The probability per unit time, λ, that a given unstable particle of system, such as a radioactive atom, will undergo spontaneous transformation. It is defined by the equation $dN/dt = -\lambda N$, where N is the number of untransformed particles or systems existing at time t. It is the reciprocal of the **mean life** of the given system before undergoing transformation.

DISINTEGRATION CONSTANT, PARTIAL. One of **disintegration constants** of a particle or system that undergoes more than one mode of disintegration. (See **branching.**)

DISINTEGRATION ENERGY, GROUND STATE. The disintegration energy of a nuclear disintegration when all the reactant and product nuclei end in their ground states. (See **disintegration, nuclear.**)

DISINTEGRATION ENERGY, NUCLEAR. The energy evolved, or the negative of the energy absorbed, in a nuclear disintegration: symbol Q. It is equal to the energy equivalence of the sum of the masses of the reactants minus the sum of the masses of the products. (For each reactant or product which is a nucleus, the appropriate mass is that of the corresponding neutral atom.) If the disintegration energy is positive, the disintegration is exothermic; if it is negative, the disintegration is endothermic. Radioactive disintegrations have positive Q-values; nuclear reactions may have positive values of either sign. Sometimes the term nuclear disintegration energy is applied to the ground-state disintegration energy. (See **disintegration energy, ground-state.**)

DISINTEGRATION FAMILY. A synonym for **radioactive series.**

DISINTEGRATION, NUCLEAR. Any transformation or change involving **nuclei.** If the disintegration is spontaneous, it is said to be **radioactive;** if it results from a collision, it is said to be induced. Despite its literal meaning, the term nuclear disintegration refers also to **radiative capture, inelastic scat-**

tering, β-transformations, and **isomeric transition.** (See **radioactivity; reaction, nuclear.**)

DISINTEGRATION SERIES. See **radioactive series.**

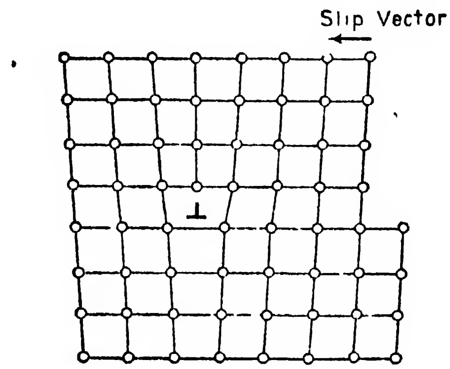
DISINTEGRATION VOLTAGE. In a hot-cathode gas tube, the cathode is normally protected from positive-ion bombardment by electron space-charge. However, if the anode potential is raised sufficiently, the space charge is removed and destructive positive-ion bombardment of the cathode occurs. The lowest voltage at which this action occurs is called the disintegration voltage. The magnitude of this voltage changes with cathode age and temperature.

DISLOCATION. A type of imperfection in a crystalline solid generated as follows: A closed curve is drawn within the solid, and a cut made along any simple surface which has this curve as boundary. The material on one side of this surface is displaced by a fixed amount (the **Burgers vector**) relative to the other side. Any gap or overlap is made good by the addition or removal of material, and the two sides are then rejoined, leaving the strain displacement intact at the moment of rewelding, but afterwards allowing the medium to come to internal equilibrium. If the Burgers vector represents a translation vector of the lattice, the weld is invisible, and the dislocation is characterized only by the original curve, or **dislocation line** and by the Burgers vector.

A dislocation line may only terminate at the surface of the crystal. The energy of a dislocation (see **dislocation, energy of**) is largely stored as strain in the surrounding lattice. The important property of a dislocation is its ability to move quite easily through the lattice, and hence to allow the rapid propagation of **slip.** The general dislocation defined above usually separates into its components, **edge** and **screw dislocations,** which may be treated as rather stable entities in the theory. Direct evidence for the existence of dislocations is the observation of **dislocation networks** in crystals of silver bromide, and, for their motion, from the **spiral growth** patterns in crystals.

DISLOCATION(S), DENSITY OF. The concentration of **dislocation lines,** i.e., the number intersecting a unit area in the crystal, is believed to vary from about $10^8/\text{cm}^2$ in good natural crystals through 10^9 in good artificial crystals, up to $10^{12}/\text{cm}^2$ in **cold-worked** specimens. These estimates are based on the energy stored by cold work, on x-ray analysis, and on measurements of electrical resistivity.

DISLOCATION, EDGE. A **dislocation** whose **Burgers vector** is normal to the line of the dislocation. An edge dislocation may be thought of as caused by inserting an extra plane of atoms terminating along the line of the dislocation—for example, if the dislocation were along the Z-axis and its Burgers



DISLOCATION, EDGE

The symbol at the center is used to denote an edge dislocation of this sign. The arrangement of atoms in this region is only approximate. (By permission from "Dislocations in Crystals" by Read, Copyright 1953, McGraw-Hill Book Co., Inc.)

vector along the X-axis, then one might think of an extra half plane of atoms being inserted at the surface $x = 0$, $y > 0$. Such a dislocation would be of positive sign. An edge dislocation may move easily only parallel **to its** Burgers vector, i.e., in its **slip plane.**

DISLOCATION, ENERGY OF. This is measured per unit length of **dislocation line** and is given approximately by

$$\frac{\mu b^2}{4\pi(1 - \nu)} \ln \left(\frac{r_1}{r_0}\right)$$

where μ is the **shear modulus,** b is the length of the **Burgers vector.** ν is **Poisson's ratio** for an **edge dislocation** or zero for a **screw dislocation.** Here, r_1 and r_0 are rather indeterminate, being respectively the distance to the "next" dislocation (or to the edge of the crystal) and the radius of the singular region, surrounding the dislocation line where ordi-

nary elasticity theory does not hold (say 10^{-7} cm). Most of this energy is thus stored as elastic deformation at large distances from the dislocation.

DISLOCATION, EXTENDED. In the **close-packed** structures it is possible to construct an extended dislocation by laying down a strip of **stacking fault** edged by two lines across which **slip** has occurred (**partial dislocations**). In each case the slip is not a whole **lattice constant,** but only into one of the alternative stacking positions. However, the whole structure is equivalent to an edge dislocation (see **dislocation, edge**), and it is believed that this is the normal form of such a dislocation in these lattices.

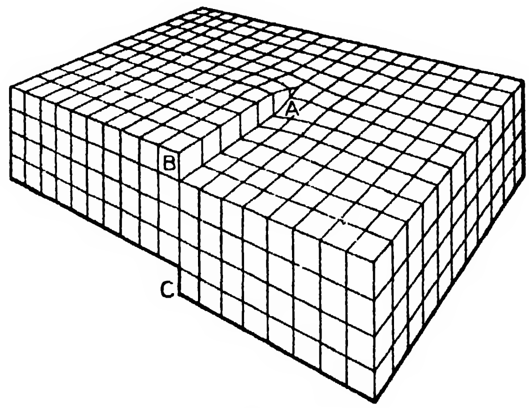
DISLOCATION(S), FORCES BETWEEN. Edge dislocations (see **dislocation, edge**) of the same sign repel each other along the line between them, but are most stable when arranged vertically above each other. Edge dislocations of opposite signs attract one another, but otherwise prefer to lie so that the line between them makes an angle of 45° with their slip planes. Screw dislocations (see **dislocation, screw**) of opposite sign attract, of like sign repel.

DISLOCATION LINE. The curve separating displaced and undisplaced portions of a crystal, and thus at the center of a **dislocation.** Within a distance of one or two **lattice constants** of the dislocation line the atoms are displaced by an amount more than can be represented fairly as a strain A screw dislocation (see **dislocation, screw**) may have a substantial hole down the dislocation line, through which impurity atoms may diffuse.

DISLOCATION NETWORKS. Hexagonal networks of **dislocation lines** have been observed in crystals of silver bromide, probably corresponding to **grain boundaries.**

DISLOCATION, PARTIAL. The line at the edge of an extended dislocation (see **dislocation, extended**) where **slip** has occurred, but not through a whole **lattice constant.**

DISLOCATION, SCREW. A **dislocation** whose **Burgers vector** is parallel to the line of the dislocation. In a screw dislocation the **atomic planes** are joined together in such a way as to form a spiral staircase, winding round the line of the dislocation. A screw dislocation is capable of easy movement in any direction normal to itself. The **growth spirals** formed in **crystal growth** appear where such dislocations intersect the surface.



SCREW DISLOCATION

The dislocation AD (of which only the end A is visible) is parallel to the line BC which is parallel to the slip vector (By permission from "Dislocations in Crystals" by Read, Copyright 1953, McGraw-Hill Book Co, Inc)

DISLOCATION, STRESS CONCENTRATION DUE TO. About an edge dislocation (see **dislocation, edge**) the **stresses** may be written

$$\sigma_{rr} = \sigma_{\theta\theta} = -\frac{\mu b}{2\pi(1-\nu)}\frac{\sin\theta}{r},$$

$$\sigma_{r\theta} = \frac{\mu b}{2\pi(1-\nu)}\frac{\cos\theta}{r}$$

where r and θ are polar coordinates about the line, θ being measured from the **slip** plane

For a screw dislocation in the z-direction (see **dislocation, screw**) the stresses are

$$\sigma_{xz} = -\frac{\mu b}{2\pi}\frac{y}{x^2+y^2}, \quad \sigma_{yz} = \frac{\mu b}{2\pi}\frac{x}{x^2+y^2},$$

$$\sigma_{\theta z} = \frac{\mu b}{2\pi r}$$

(b is the **Burgers vector,** μ, the **shear modulus,** ν, **Poisson's ratio**).

DISORDER, ENTROPY OF. See **entropy of disorder.**

"DISORDER PRESSURE." The contribution to the pressure that arises through the existence of a contribution to the **entropy of a**

liquid through molecular disorder, i e, from the **communal entropy.**

DISPERSE MEDIUM. (Dispersive or dispersion medium, continuous phase) The medium in which a **colloid** is dispersed, in a manner analogous to that of the solvent in a true solution.

DISPERSE PARTICLES. (Disperse phase) The particles of **colloid** in a colloidal system

DISPERSE PHASE. The distributed phase in a **colloidal system,** i e, the phase which is composed of the distributed particles.

DISPERSE SYSTEM. A **colloidal system,** consisting of two phases. the disperse phase (the one forming particles) and the dispersion medium (the medium in which the particles are distributed).

DISPERSING SYSTEM. A system used to separate various wavelengths of radiant energy

DISPERSION. (1) The process of separating a radiation, a complex sound wave, etc, in accordance with some characteristic such as frequency, wavelength or energy, into components. For example, a **prism** or **grating** disperses white light by sending light of different wavelengths in different directions (2) Quantitatively, a general measure of such dispersion is the derivative of the deviation with respect to that variable (wavelength, frequency, etc). (3) Dispersion of a medium is also expressed as the rate of change of index of refraction with wavelength (or frequency, etc). (See **group velocity.**)

DISPERSION, ACOUSTIC. The separation of a complex sound wave into its various frequency components, usually caused by a variation with frequency of the **wave velocity** of the medium The rate of change of the velocity with frequency is used as a measure of the dispersion.

DISPERSION, ANOMALOUS. See **anomalous dispersion.**

DISPERSION EFFECT. The attraction between electrically neutral molecules arising from the tendency of their temporary **dipoles** to align themselves in a manner so as to produce a net attractive force. (See **van der Waals forces.**)

DISPERSION, ELECTRIC. The preparation of **colloidal solutions** by means of the electric current Two methods are commonly employed: (1) cathode dispersion, in which the cathode is made of the material which is to form the disperse phase, the anode is of platinum or other inert metal, and a high potential is used; (2) electric arc formation between wires of various metals under water. Many metals (platinum, silver, iridium, cadmium, etc) give metal sols by method 2; other metals (thallium, zinc, iron, aluminum, etc) give hydroxide sols only. Metals which are above hydrogen in the **electromotive force series** are not likely to yield metal **sols** in water.

DISPERSION FORCES. The force of attraction between molecules possessing no permanent **dipole.** The interaction energy is given by

$$U_D = -\frac{3}{4} h \frac{V_0 \alpha^2}{r^6}$$

where h is Planck's constant, V_0 a characteristic frequency of the molecule, r the distance between the molecules and α the polarizability.

DISPERSION FORMULA. See **Cauchy formula; Hartman formula.**

DISPERSION IN GASES, RELAXATION THEORY TREATMENT OF SOUND. The analysis of sound dispersion in gases in which it is assumed that the passage of the sound wave disturbs the equilibrium of energy distribution among translational, rotational and vibrational degrees of freedom. The time lag involved in the return to equilibrium results in an increase in the sound velocity at higher frequencies, as well as an absorption of the sound energy

DISPERSION, IRRATIONAL. A phenomenon exemplified by the case in which two **prisms** of different substances but of such **refracting angles** as to give equal angular separation between two spectral lines will not, in general, give equal angular separations between one of the lines and some third line, even if it lies between the initial two lines.

DISPERSION, LINEAR. The derivative $dx/d\lambda$, where x is distance along the **spectrum** and λ is the **wavelength.** Linear dispersion is usually expressed as millimeters per Angstrom.

DISPERSION OF AN INSTRUMENT. The dispersion of a dispersing instrument is commonly expressed as $dL/d\lambda$ or $d\theta/d\lambda$ where L is distance along the final image, and θ is the **angle of deviation.**

DISPERSION OF ROTATION. The **angle of rotation** of the plane of vibration in optically active substances is $\rho = K/\lambda^2 + a$ where K is constant and a depends on natural free periods of vibration in the crystal. This relation is called the dispersion of the rotation.

DISPERSION, RECIPROCAL LINEAR. The derivation $d\lambda/dx$, where λ is **wavelength** and x is the distance along the **spectrum.** The reciprocal linear dispersion is usually expressed in Ångstroms per millimeter.

DISPERSIONAL FREQUENCY. The frequency corresponding to the anomalous dispersion (see **anomalous dispersion**) at an absorption discontinuity.

DISPERSITY. The degree of dispersion of a **colloid,** i.e., the extent to which the dimensions of the individual particles have been reduced. Expressed numerically in terms of **specific surface.**

DISPERSIVE POWER. (1) The ratio of the difference in **deviation** of light of two different wavelengths relative to the deviation for light whose wavelength is an average of the two. Thus, if D_A, D_B are the **deviations** for wavelength $\lambda = A$ and $\lambda = B$ and if D_C is that for light of some intermediate wavelength $\lambda = C = \frac{1}{2}(A + B)$, then the dispersive power is given by

$$d = \frac{D_A - D_B}{D_C}.$$

(2) A quantity which is approximately equal to the reciprocal of the dispersive power, also referred to as the Abbe number or as ν-value, is defined by lens designers and manufacturers of optical glass as

$$\nu = \frac{n_D - 1}{n_F - n_C}$$

where n_D, n_F and n_C are the refractive indices of the glass for the **D, F,** and **C** Fraunhofer **lines.**

DISPERSIVITY. Differential **refractivity.** The difference in refractivity of the same medium for various wavelengths of radiant energy.

DISPERSIVITY, MOLAR. The difference in molar **refraction** at two wavelengths.

DISPERSIVITY, SPECIFIC. The difference between the specific **refractions** of two wavelengths of radiant energy.

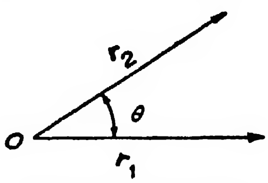
DISPERSOID. A **colloidal system** in which the dispersity is relatively great, as in **emulsoids** and **suspensoids.**

DISPLACEMENT. (1) The vector representing the change in position of a particle. In one-dimensional motion such as a **simple harmonic oscillator,** the displacement can be considered as a scalar. (See also **displacement, angular; linear.**) (2) In a piston and cylinder mechanism, the volume swept out by the piston face. It is assumed that the face of the piston is coplanar. Given the bore and stroke as D and L, the number of cylinders n, the displacement is:

$$\frac{\pi D^2 L n}{4}.$$

(3) The portion of a ship which is immersed displaces a certain weight of water. According to Archimedes' principle, a body immersed in water is buoyed up by a force equal to the weight of water displaced by the body. Hence the displacement of a ship in tons of water is equal to the weight of the ship and of its contents. Various legal and conventional definitions of the displacement of a ship are related, but not equal, to the buoyancy.

DISPLACEMENT, ANGULAR. If the **vector $\mathbf{r}_1$** is displaced to the new position $\mathbf{r}_2$, the



Angular displacement

angular displacement θ is defined as the angle between the two vectors. It is itself a vector only for infinitesmal displacements.

DISPLACEMENT ANTIRESONANCE. See **antiresonance, displacement.**

DISPLACEMENT CELL. See **cell, displacement.**

DISPLACEMENT, COMPLEX. In solving for the transient and steady state behavior of a vibrating system undergoing **forced oscillations,** it is often mathematically useful to construct a complex displacement $x_c = x + ix'$, where x is the real, and x', the imaginary part.

DISPLACEMENT CURRENT. See **current, displacement.**

DISPLACEMENT, ELECTRIC. See **electric flow density.**

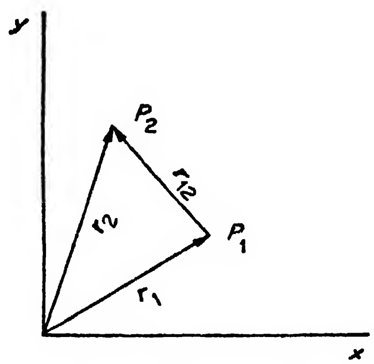
DISPLACEMENT INTERFEROMETER. An optical instrument consisting of an arrangement of mirrors, and used in conjunction with a dispersive system for measuring small displacements.

DISPLACEMENT LAWS. (1) See **Wien laws.** (2) Statements of the changes in atomic number Z and mass number A of a **nuclide** that accompany the various types of **radioactive** disintegration. The name originated from the circumstance that a change in atomic number results in a displacement of the daughter relative to the parent in the periodic table of the elements.

TABLE

Type of Disintegration		δZ	δA
Alpha		−2	−4
Beta	electron emission	+1	0
	position emission	−1	0
	electron capture	−1	0
Isomeric transition		0	0

DISPLACEMENT, LINEAR. The position of a particle P_1 may be specified by a vector



Linear displacement

$\mathbf{r}_1$, drawn from a fixed reference point in a primary inertial system. When the particle changes its position to P_2, a new vector $\mathbf{r}_2$ must be drawn to specify the new position The vector $\mathbf{r}_{12} = \mathbf{r}_2 - \mathbf{r}_1$ represents the **displacement** of the particle. If, during the interval under consideration, the instantaneous direction of $\mathbf{r}_{21}$ remains fixed in direction, the displacement is linear

DISPLACEMENT RESONANCE. See **resonance, displacement.**

DISSECTOR TUBE. See **tube, dissector.**

DISSIPATION. (1) The interaction between matter and energy incident upon it, such that the portion of the energy used up in the interaction is no longer available for conversion into useful work. (2) A persistent loss of mechanical energy because of the presence of frictional or frictionlike forces. (3) In free oscillatory motion, a persistent loss of mechanical energy due to presence of frictionlike resistance to motion which eventually exhausts the total energy of the system and causes it to come to rest. Such motion is said to be damped (See **damped oscillations.**)

DISSIPATION ELEMENT, ACOUSTIC. An element (see **element, acoustic**) which brings about dissipation of some or all of the acoustic energy flowing through it.

DISSIPATION FACTOR. The reciprocal of Q, the **storage factor.**

DISSIPATION FACTOR, DIELECTRIC. See **dielectric dissipation factor.**

DISSIPATIVE FORCE. Any force which opposes motion and whose action converts mechanical into thermal energy

DISSIPATIVE FUNCTION (RAYLEIGH). One half the rate of decrease of total mechanical energy in a **dissipative system.** The function is equal to $(R/2)(dx/dt)^2$ where R is the effective resisting force constant and dx/dt is the instantaneous **velocity.** (See **damped oscillations.**)

DISSIPATIVE SYSTEM. (1) A mechanical system in which **dissipation** takes place. (2) In an electrical system, composed of a capacitance, resistance and inductance, free oscillations can be set up which eventually damp out. The electrical energy originally stored

in the condenser is dissipated into thermal energy in the resistance.

DISSOCIATION CONSTANT. (1) The **equilibrium constant** for a chemical reaction which breaks up one molecule to form two or more simpler molecules. (2) Following from (1), the equilibrium constant for the **ionization** of an **electrolyte.** It is given by the product of the activities of **cation** and **anion,** divided by the activity of the unionized electrolyte. (See **mass action law.**)

DISSOCIATION CONTINUA. Continuous absorption spectra (see **spectrum, absorption**) corresponding to a dissociation.

DISSOCIATION, DEGREE OF. See **degree of dissociation.**

DISSOLVING. The complete mixing with a liquid of a gas or solid composed of different molecules.

DISSONANCE. (1) When two or more musical tones played simultaneously produce an unpleasant effect (due to beats) on the listener, the tones are said to be in dissonance. (2) The formation of maxima and minima by the superposition of two sets of **interference fringes** from light of two different wavelengths.

DISSYMMETRICAL NETWORK. See **transducer, dissymmetrical.**

DISSYMMETRICAL TRANSDUCER. See **transducer, dissymmetrical.**

DISSYMMETRY FACTOR OR ANISOTROPY FACTOR. A quantity used to express conveniently the magnitude of circular dichromism (refer to the **Cotton effect**). It is defined by the following formula:

$$g = \frac{(\kappa_l - \kappa_r)}{\kappa}$$

where g is the dissymmetry factor, κ_l and κ_r are the absorption indices for the left- and right-circularly polarized light, and κ is the absorption index for ordinary light of the same wavelength.

DISTANCE. The distance between two points is the length of the straight line joining the two points, i.e., the number of times that a specified measuring rod must be successively applied to cover this line completely.

DISTANT PARALLELISM. Property of a space if any vector, when taken by parallel displacement (see **affinely connected space**) around any closed curve, returns to itself.

DISTORTION. (1) One of the five **geometrical aberrations** of optics with spherical surfaces. This aberration is due to the variation in magnification with the distance from the axis. (2) In acoustics, a change in wave form. Noise and certain desired changes in wave form, such as those resulting from **modulation** or **detection,** are not usually classed as distortion. (3) In electromagnetics, an undesired change in wave form.

DISTORTION AND NOISE METER. An instrument which removes the fundamental frequency of the signal being measured by means of a **null network.** That which remains after the removal of the **fundamental** may be measured as total distortion and noise.

DISTORTION, BIAS TELEGRAPH. Distortion in which all mark pulses are lengthened (positive bias) or shortened (negative bias). It may be measured with a steady stream of "unbiased reversals," square waves having equal-length **mark-** and **space-pulses.** The average lengthening or shortening gives true bias distortion only if other types of distortion are negligible.

DISTORTION, CHARACTERISTIC TELEGRAPH. Distortion which does not affect all **signal pulses** alike, the effect on each transition depending upon the signal previously sent, due to remnants of previous transitions or **transients** which persist for one or more **pulse lengths.** Lengthening of the **mark pulse** is positive, and shortening, negative. Characteristic distortion is measured by transmitting "biased reversals," square waves having unequal mark- and space-pulses. The average lengthening or shortening of mark-pulses, expressed in per cent of unit pulse-length, gives a true measure of characteristic distortion only if other types of distortion are negligible.

DISTORTION, DELAY. Distortion due to variation of the **propagation time** of the system with frequency.

DISTORTION, DEVIATION. Distortion in an FM receiver caused by inadequate **band-**

width, inadequate **amplitude-modulation** rejection, or inadequate **discriminator** linearity.

DISTORTION, FORTUITOUS TELEGRAPH. **Distortion** which includes those effects that cannot be classified as bias or characteristic distortion, and is defined as the departure, for one occurrence of a particular signal **pulse,** from the average combined effects of **bias** and **characteristic distortion.** Fortuitous distortion varies from one signal to another and is measured by a process of elimination over a long period. It is expressed in per cent of unit pulse.

DISTORTION, FREQUENCY. A term commonly used for that form of **distortion** in which the relative magnitude of the different frequency components of a complex wave are changed in transmission. When referring to the distortion of the **phase** versus **frequency characteristic,** it is recommended that a more specific term such as "phase-frequency distortion" or "delay distortion" be used.

DISTORTION, GEOMETRIC. In television, any aberration which causes the reproduced picture to be geometrically dissimilar to the perspective plane-projection of the original scene.

DISTORTION, HARMONIC. Nonlinear distortion characterized by the appearance in the output of harmonics other than the fundamental component when the input wave is sinusoidal. Harmonic distortion is sometimes called amplitude distortion.

DISTORTION, KEYSTONE. The keystone-shaped **raster** produced by **scanning** in a rectilinear manner, with constant-amplitude sawtooth waves, a plane-target area which is not normal to the average direction of the beam.

DISTORTION, NONLINEAR. **Distortion** caused by a deviation from a desired linear relationship between specified measures of the output and input of a system. The related measures need not be output and input values of the same quantity; e g., in a linear detector, the desired relation is between the output signal voltage and the input modulation envelope.

DISTORTION POLARIZATION. See **induced polarization.**

DISTORTION, TOTAL TELEGRAPH. Telegraph transmission impairment, expressed in terms of time displacement of **mark-space** and **space-mark** transitions from their proper positions relative to one another, in per cent of the shortest perfect pulses called the unit pulse. (Time lag affecting all transitions alike does not cause distortion.) Telegraph distortion is specified in terms of its effect on code and terminal equipment. "Total Morse telegraph distortion" for a particular mark or space pulse is expressed as the algebraic sum of time displacements of space-mark and mark-space transitions determining the beginning and end of the pulses, measured in per cent of unit pulse. Lengthening of mark is positive, and shortening negative. "Total start-stop telegraph distortion" refers to the time displacement of selecting-pulse transitions from the beginning of the start pulse expressed in per cent of unit pulse.

DISTRIBUTED CAPACITANCE. See **capacitance, distributed.**

DISTRIBUTED CONSTANT (FOR A WAVEGUIDE). A circuit parameter that exists along the length of a **waveguide.** For a transverse **electromagnetic wave** on a two-conductor **transmission line,** the distributed constants are series resistance, series inductance, shunt conductance and shunt capacitance per unit length of line.

DISTRIBUTION COEFFICIENT. The ratio between the concentrations of a solute in two immiscible solvents which are in contact. (See **law of distribution.**) Called also partition coefficient.

DISTRIBUTION CONTROL. In television, . **linearity control.**

DISTRIBUTION, LAW OF. (The partition law, distribution law of Nernst.) If two partly or nearly immiscible liquids are in contact and a substance which is soluble in both liquids be added to the system, the addend will be distributed between them in such a way that the ratio of the concentrations of the two solutions formed is a constant regardless of the quantity of solute. (Measurable deviations from this law take place, especially in concentrated solutions, because of association, ionization, chemical action, etc.) The constant is termed the distribution ratio, constant, or coefficient, and the partition coefficient.

DISTRIBUTION LAW OF MAXWELL. See **law of Maxwell, distribution.**

DISTRIBUTION OF MOLECULAR VELOCITIES, LAW OF. At any given temperature different molecules of a gas have different velocities which range from very small to very large values. A large majority of molecules have velocities falling in a narrow range, but a small fraction of molecules have very low or high velocity. As the temperature is raised the maximum in the velocity distribution curve shifts to higher velocities and flattens out. (See **law of Maxwell, distribution.**)

DISTRIBUTIVE LAW. An **operator** A obeys this law if its effect on a sum of functions is $A(f_1 + f_2 + f_3 + \cdots) = Af_1 + Af_2 + Af_3 + \cdots$. The trigonometric functions do not obey the distributive law since $\sin (x + y + z + \cdots) \neq \sin x + \sin y + \sin z + \cdots$.

DISTURBANCE. A local departure from the normal or average wind condition of any part of the world or, in other words, a feature of what is sometimes called the "secondary" circulation of the atmosphere, as distinguished from the general circulation In every-day usage disturbance has come to be synonymous with **cyclone** and **depression.**

DIVERGENCE. The **scalar product** of the **differential operator** ∇ and a **vector.** In Cartesian coordinates

$$\nabla \cdot \mathbf{V} = div\, \mathbf{V} = \frac{\partial V_x}{\partial x} + \frac{\partial V_y}{\partial y} + \frac{\partial V_z}{\partial z}.$$

If **V** represents at each point in space the direction and magnitude of flow of some fluid, such as water or a gas, thermal, or electrical flux, then div **V** equals the rate of decrease of fluid per unit volume. (See also **Gauss theorem** and **Green theorem.**)

DIVERGENCE LOSS (SOUND). That part of the **transmission loss** which is due to the divergence or spreading of the sound rays in accordancy with the geometry of the system (e.g., spherical waves emitted by a point source).

DIVERGENCE THEOREM. See **Gauss theorem** and **Green theorem.**

DIVERGENT. If an infinite series does not **converge,** it is said to be **divergent.** The sum of the series may be positively infinite, negatively infinite, or it may **oscillate** between either finite or infinite values.

DIVERSITY RECEPTION. Fading has been found to vary from place to place at a given time. Thus if a radio signal is received simultaneously at points separated by a few wavelengths' distance it is found that the outputs of the receivers do not all fade together. Diversity reception is a method of utilizing this effect to minimize the fading. Basically such a system consists of 2 or more (3 is quite common) antennae separated by several wavelengths (at least 10 times the wavelength of the received wave is desirable and 3 antennae placed at the vertices of an equilateral triangle give the best positioning) feeding separate radio-frequency receiver channels. The outputs of these channels are then combined to give a single output. By means of automatic gain control circuits the antenna receiving a non-faded signal supplies most of the output and as the signals at the different antennae fade out and back in, the control system acts to maintain a constant output level. While such a system, because of its complexity, is not suitable for home reception, it is widely used for reception of foreign broadcasts for rebroadcasting in this country. It is also used for transoceanic telephone reception

DIVIDING NETWORK. See **network, crossover.**

DIXONAC. An aqueous coating of graphite used as a conductive coating on the inside of some electron tubes such as **kinescopes.** Also known as **Aquadag.**

DOG HOUSE. A small structure housing tuning-apparatus, placed at the base of a transmitting **antenna.**

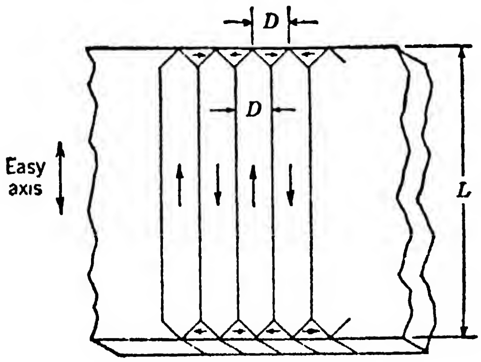
DOHERTY AMPLIFIER. See **amplifier, Doherty.**

DOLDRUMS. The tropical regions of the Equatorial Belt characterized by calms and light, shifting winds with frequent thunderstorms, squalls and heavy showers.

DOMAIN. (1) A two-dimensional region of space, together with its bounding curve. (See also **variable** and **set.**) (2) A region of spontaneous **electric** or **magnetic polarization in**

a single direction in a ferroelectric or **ferromagnetic crystal.** Inside a domain the polarization is saturated, and is a function only of the temperature. The size and shape of a domain depends on the material and its treatment. The boundary between domains is known as a **Bloch wall.**

DOMAIN STRUCTURE. The theory of the macroscopic behavior of **ferromagnetic** and **ferroelectric** crystals depends on their consisting of large numbers of **domains,** each polarized to saturation but pointing in different directions so as to minimize the energy.



Domain structure.

Flux closure domain configuration in a uniaxial crystal. (By permission from Introduction to Solid State Physics by Kittel. Copyright 1953 John Wiley & Sons Inc.)

An applied field tends to make those domains grow which are already favorably oriented, at the expense of those opposed to the field. Owing to the **anistropy energy,** domains tend to be oriented along certain directions of easy magnetization, but the detailed arrangement of domains in a crystal is a complicated compromise between the tendency of each domain to be as large as possible and the necessity of creating closed loops of magnetic flux.

DOMAIN STRUCTURE OF SUPERCONDUCTOR. The pattern of intermingled normal and superconducting regions characteristic of the **intermediate state.**

DOMAIN THEORY. It is now known that **ferromagnetic** materials are composed of many small magnets or domains. Each domain is in a saturated condition, the **magnetization** of the material depends upon the orientation of the magnetized domains. (See **domain [2].**)

DOMINANT MODE OF PROPAGATION (TRANSMISSION). The **mode of propagation** of the dominant wave. (See **wave, dominant.**)

DOMINANT WAVE. See **wave, dominant.**

DOMINANT WAVELENGTH. The **wavelength** of **light** of a single frequency, which matches a color when combined in suitable proportions with a reference standard light. Light of a single frequency is approximated in practice by the use of a range of wavelengths within which there is no noticeable difference of color. Although this practice is ambiguous in principle, the dominant wavelength is usually taken as the average wavelength of the band used in the mixture with the reference standard in matching the sample. Many different qualities of light are used as reference standards under various circumstances. Usually the quality of the prevailing illumination is acceptable as the reference standard in the determination of the dominant wavelength of the colors of objects.

DONNAN EQUILIBRIUM. If a solution containing a salt with a non-diffusible ion is separated from a solution of an electrolyte containing diffusible ions by a semipermeable membrane, then at equilibrium an electrostatic difference of potential termed a "membrane potential" will be established between the two solutions separated by the membrane. A difference in **osmotic pressure** will also be established at equilibrium. Proteins in the presence of simple salts exhibit this phenomenon.

DONOR (IN A SEMICONDUCTOR). See **impurity, donor**

DONOR ENERGY LEVEL. An energy level associated with a donor impurity in a semiconductor. (See **impurity, donor.**)

DONOR IMPURITY. See **impurity, donor.**

DONUT, DOUGHNUT. An **accelerating tube** of toroidal shape.

DONUTRON. A form of tunable **magnetron.**

DOOR-KNOB TUBE. See **tube, door-knob.**

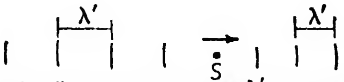
DOPING. Addition of impurities to a **semiconductor,** or production of a deviation from

stoichiometric composition, to achieve a desired characteristic.

DOPING COMPENSATION. Addition of donor impurities (see **impurity, donor**) to a P-type semiconductor (see **semiconductor, P-type**) or of acceptor impurities (see **impurity, acceptor**) to an N-type semiconductor (see **semiconductor, N-type**).

DOPPLER BROADENING. A spreading of radiation frequencies that are potentially all the same, with a resulting broadening of the corresponding spectral line, which takes place when radiating nuclei, atoms or molecules do not all have the same velocity relative to the observer, so that they give rise to different **Doppler shifts.** For example, since molecules of luminous gases have a **Maxwell distribution of velocities**, these effects produce a range of observed frequencies symmetrically distributed about the frequency of the atoms at rest, this range increasing with increasing temperature; and there is a distribution of intensities throughout the broadened line that is determined by the Maxwell distribution of velocities. In absorption spectra, a similar broadening of the lines can result from the motions, relative to the observer, of the absorbing atoms or molecules. In nuclear physics, thermal motions of the nuclei in the material under examination can contribute appreciably to the widths of resonance lines, many of which (for instance, in slow neutron absorption) have natural widths of about 1 ev.

DOPPLER EFFECTS. The effects upon the apparent frequency of a wave train produced (1) by motion of the source toward or away from the stationary observer, and (2) by mo-



Doppler effect of motion of source λ' is the altered wave length

tion of the observer toward or from the stationary source; the motion in each case being with reference to the (supposedly stationary) medium.

The Doppler effects are of great importance in the case of light (for which it is quite impossible to distinguish between them because only the **relative velocity** of observer and source is of relativistic importance).

The slight abnormality (Doppler shift) in the positions of the spectrum lines from a star, for example, affords a fairly accurate value of the relative speed with which the star and the earth are approaching or receding from each other (the **radial velocity**). Many **double stars (spectroscopic binaries)** are recognized as such only by the doubling of their spectrum lines due to the components moving in opposite directions. The spectrum lines of gases are often broadened because of the various speeds of the molecules.

For sound waves, the observed frequency f_0, in cycles/sec, is given by

$$f_0 = \frac{v + w - v_0}{v + w - v_s} f_s$$

where v is the velocity of sound in the medium, v_0 is the velocity of the observer, v_s is the velocity of source, w is the velocity of wind in the direction of sound propagation, and f_s is the frequency of source.

For optical waves

$$f_0 = f_s \sqrt{\frac{c + v_r}{c - v_r}},$$

where v_r is the velocity of the source relative to the observer and c is the speed of light.

DOPPLER-FIZEAU PRINCIPLE. The principle underlying the **Doppler effects** as applied by Fizeau to the shifting of spectrum lines.

DOPPLER RADAR. A **radar** system which differentiates between fixed and moving targets by detecting the change in frequency of the reflected wave caused by the **Doppler effects.** The system can also measure target velocity with high accuracy.

DOPPLER SHIFT. The magnitude of the change in the observed frequency of a wave due to the **Doppler effects.** The unit is the cycle per second.

DORN EFFECT. The production of a potential difference by a powder falling through a liquid, arising from the presence of an **electrical double layer** around the particles of powder.

DOSE (DOSAGE). According to current usage, the radiation delivered to a specified

area or volume or to the whole body Units for dose specification are **roentgens** for **x-** or **γ-rays, reps** or **rems** (equivalent roentgens) for β-rays. The subject of dose units for particulate radiation and for very high energy x-rays has not been settled. In radiology the dose may be specified in air, on the skin, or at some depth beneath the surface; no statement of dose is complete without specification of location The entire question of radiation dosage units is under consideration by the International Congress of Radiology, and it is expected that new units based on the energy absorbed in tissue will be adopted.

DOSE, AIR (X-RAYS). X-ray dose expressed in **roentgens** delivered at a point in free air In radiologic practice it consists only of the radiation of the primary beam, and that scattered from surrounding air.

DOT GENERATOR. A generator whose output, when fed into a correctly-operating television system, will cause a field of regularly-spaced dots to appear on a **kinescope screen.** Used for alignment purposes.

DOUBLE AMPLITUDE. See **amplitude, peak-to-peak.**

DOUBLE-BASE DIODE. See **diode, double-base.**

DOUBLE-BASE TRANSISTOR. See **transistor, tetrode.**

DOUBLE-BETA DISINTEGRATION. A radioactive **disintegration** in which the atomic number increases by 2 units and the mass number does not change. Obviously, this process would occur when two β-particles are simultaneously emitted. Two **neutrinos** may be emitted in this process. The process is possible, but improbable

DOUBLE COMPTON SCATTERING. Process in which a photon is incident on a charged particle and two photons are given off.

DOUBLE-CURRENT GENERATOR. A **generator** having both **commutator** and **slip-rings,** so that a-c and d-c may both be taken from it.

DOUBLE DIODE. See **duodiode.**

DOUBLE LAYER, ELECTRIC. A hypothetical distribution of charge comprising a layer of positive charge and a layer of negative charge very close by. The net charge is usually zero, but fields are produced by the **dipole moments** of the elements of the double layer.

DOUBLE LAYER POTENTIAL. See **zeta potential.**

DOUBLE MODULATION. See **modulation, double.**

DOUBLE POLE-PIECE MAGNETIC HEAD. See **magnetic head, double pole-piece.**

DOUBLE-PRECISION NUMBER. A number having twice as many significant digits as are ordinarily used in a particular **computer.**

DOUBLE REFRACTION, ELECTRIC AND MAGNETIC. See **electric and magnetic double refraction.**

DOUBLE REFRACTION, FORCED. See **forced double refraction.**

DOUBLE REFRACTION, LORENTZ. See **Lorentz double refraction.**

DOUBLE REFRACTION, OPTICAL. If a crystal of one of certain substances, such as **calcite** (calcium carbonate, a common mineral) is held between the eye and a pinhole in a card, two bright dots are seen. If the crystal is rotated around the line of sight, one dot travels in a circle around the other, which remains fixed. Evidently there are two refracted rays; with the light normally incident on the natural crystal face, they make (within the crystal) an angle of about 6° 9′ The two refracted rays reveal a difference in **refractive index.** The one which remains fixed as the crystal revolves, called the ordinary ray, corresponds to a greater index than does the other, called the extraordinary ray. For sodium light the two indices of calcite are, respectively, 1 658 and 1 486. A simple test shows that the two rays consist of plane-**polarized light,** one vibrating at right angles to the other.

These phenomena were explained by Huygens (1678) as due to the fact that the ordinary wave has a spherical wave front, traveling with the same speed in all directions, just as if the medium were isotropic; while the extraordinary wave has either a maximum or a minimum speed along the optic axis, so

that its wave front is either an oblate (door-knob-shaped) or a prolate (football-shaped) spheroid.

Many crystals have two optic axes. In this case the double wave surface is a much more complicated system in which there are four points of intersection, corresponding to the two axes.

DOUBLE REGENERATION. See **regeneration, double.**

DOUBLE-SPOT TUNING. See **tuning, double-spot.**

DOUBLE-SURFACE TRANSISTOR. See **transistor, double-surface.**

DOUBLE SUPERHETERODYNE. See **heterodyne, double.**

DOUBLE TRIODE. See **duotriode.**

DOUBLE-Y RECTIFIER. See **rectifier, double-Y.**

DOUBLE ZIG-ZAG RECTIFIER. Two three-phase, half-wave zig-zag rectifiers (see **rectifier, zig-zag**) operating with their outputs effectively in parallel, but with their relative phase voltages differing by 60°. The result is equivalent to a six-phase half-wave system. (See **rectifier, polyphase.**)

DOUBLER CIRCUIT. A type of self-saturating, magnetic-amplifier circuit with a-c output. (See **amplifier, magnetic.**)

DOUBLET. (1) Two electrons which are shared by two atoms so as to form a non-polar valence bond. (See **bond, non-polar.**) (2) A pair of spectral lines resulting from transitions between a common state and two states which differ only in total angular momentum (J), i.e., have identical values of orbital (L) and spin (S) angular momenta. (3) Two stationary states having common values of (L) and (S), but different values of (J). (4) A lens, particularly an **achromat,** having two components.

DOUBLET, OSCILLATING. See **antenna, oscillating doublet.**

DRAG. In aerodynamics and hydrodynamics, that component of the force on a body which is in the direction of the mean fluid flow relative to the body.

DRAG ANGLE. In recording, the angle between the cutting **stylus** and the record when the stylus is positioned so that its tip tends to drag behind the **cutting head.** It is the opposite of **dig-in angle.**

DRAG-CUP MOTOR. See **motor, drag-cup.**

DRAG EFFECT. The effect of interionic attraction in reducing the freedom of an ion to move in an electrical field, because of the interference of the ions of opposite charge by which a given ion is surrounded. The drag effect is an essential part of the explanation of the **Debye-Hückel theory** of the anomalous properties of concentrated solutions of strong electrolytes.

DRAG, FRESNEL COEFFICIENT OF. See **Fresnel coefficient of drag.**

DRIFT. (1) Random variations in direction. (2) Random variations in a characteristic of an electromagnetic wave or signal which are continuously in one direction or the other for periods of a second or more. (3) In a magnetic amplifier (see **amplifier, magnetic**) drift is a change in the control characteristic due to unassignable causes. It is expressed in terms of the signal (usually given in watts) required to restore a specified output current to its original value. Unless otherwise stated, the time interval is 24 hours; the amplifier is operated at its rating except for the output current which is at the lower value given in the response time definition; and all effects other than changes of supply voltage, frequency and ambient temperature are included. (4) In a balanced amplifier, drift is any unbalance which occurs with time or change in operating conditions after the balance control has once been set.

DRIFT, ABSOLUTE. In a **magnetic amplifier,** absolute drift is expressed in terms of the input signal required to rebalance the amplifier. It may be measured in terms of watts, current, or ampere-turns.

DRIFT, PER CENT. Of a balanced **magnetic amplifier,** the ratio of the output drift to the rated output.

DRIFT, PER CENT SIGNAL. Of a balanced **magnetic amplifier,** the ratio between the input drift measured in ampere-turns and the maximum signal ampere-turns.

DRIFT MOBILITY (IN A HOMOGENEOUS SEMICONDUCTOR). The average **drift velocity** of **carriers** per unit electric field. It is to be noted that in general the mobilities of electrons and **holes** are different.

DRIFT SPACE. In velocity-modulation tubes (see **tube, velocity-modulation**), the space between **buncher** and **catcher.**

DRIFT VELOCITY. The average velocity with which any **carrier** drifts under the influence of an electric field, and hence carries current in a **semiconductor.**

DRIVE-HOLES. Holes in a **recording disk** designed to be engaged by the drive-pin to prevent slippage between the disk and the turntable.

DRIVE-PIN. An off-center pin on a recording turntable designed to engage the **drive-hole** to prevent slippage of the recording disk.

DRIVEN ANTENNA. See **antenna, directional.**

DRIVEN ELEMENT. In an **antenna array,** the element or elements which are connected to the receiver (or transmitter).

DRIVER STAGE. The stage designed to supply the input signal power required by the last or final stage.

DRIVING-FORCE RESONANCE. See **resonance, frequency of.**

DRIVING-POINT IMPEDANCE. See **impedance, driving-point.**

DRIVING POWER. The power which is required by an **amplifier** which operates in the positive grid region some portion of the time For a **class C amplifier,** this power is very nearly equal to the average grid current times the crest value of the exciting voltage.

DRIVING SIGNALS. See **signals, driving.**

DRIZZLE. Numerous very small liquid droplets whose diameter is less than 0.5 mm and whose rate of fall is usually less than 3 m per sec. Normally the drops seem to float downward.

DROP. A small volume of liquid, bounded almost completely by free surfaces.

DROP FORMATION. The simplest way to form drops is to allow liquid to flow slowly from the open lower end of a vertical tube of small diameter. When the pendent drop exceeds a certain size it is no longer stable and detaches itself and falls. Drops may also be formed by condensation of a supercooled vapor or by atomization of a larger mass of liquid.

DROP WEIGHT. The weight of the largest drop that can hang from the end of a tube of radius, a, is nearly

$$mg = 2\pi a\gamma \cos \alpha$$

where γ is the surface tension of the liquid, α is the angle of contact with the tube. This relationship is the basis of a convenient method of measuring **surface tension.**

DROP WEIGHT METHOD. See **surface tension, methods of measurement.**

DRUDE EQUATION. A relationship between the specific **rotation** of an **optically-active** substance and the wavelength of the light, of the form:

$$[\alpha] = \frac{k}{\lambda^2 - \lambda_0^2}$$

where $[\alpha]$ is the specific rotation, λ the wavelength, and k and λ_0^2 are constants, known as the rotation constant and the dispersion constant of the substance

DRUDE THEORY OF ELECTRONS IN METALS. The original form of the **free electron theory of metals** in which the electrons were treated as a gas of classical particles. This theory is capable of explaining the high electrical conductivity of metals, but attributes to them far too large a specific heat, and has to be supplemented by the postulate that the electrons obey **Fermi-Dirac,** rather than **Maxwell-Boltzmann statistics.**

DRUM SPEED. The number of scanning lines per minute in a **facsimile system.**

DRUMSKIN ACTION. The vibration of a wall as a whole under the action of an incident sound wave.

DRY-DISC RECTIFIER. See **rectifier, dry-disc.**

DRY ELECTROLYTIC CAPACITOR. See **capacitor, dry electrolytic.**

DRYSDALE POTENTIOMETER. See **potentiometer, Drysdale.**

DUAL-AUTOMATIC RADIO COMPASS. See **radio compass, dual-automatic.**

DUAL-DIVERSITY RECEIVER. See **receiver, dual-diversity.**

DUAL MODULATION. See **modulation, dual.**

DUAL NETWORKS. See **networks, structurally dual.**

DUAL-TRACK RECORDING. In **magnetic tape recording,** the recording of information on two channels on one strip of tape. Commercial systems usually record up one side and down the other, thus effectively doubling the tape length.

DUALITY OF DESCRIPTION. See **complementarity principle.**

DUANE AND HUNT LAW. **X-rays** generated by electrons striking a target cannot have a frequency greater than eV/h where e is the electronic charge, V the exciting voltage and h is **Planck's constant.** This is a simple consequence of **quantum mechanics.**

DUBBING. The combining of two or more sources of sound into a complete **recording,** at least one of the sources being a recording.

DUCT, LINED OR ABSORBING. Tubes used in ventilator and exhaust systems to provide a high degree of attenuation for audio-frequency waves while offering low resistance to continuous flow of air. For rectangular conduit lines with absorbing material, the attenuation, in *db/ft*, is given empirically by

$$\text{attenuation (db/ft)} = 12.6\alpha^{1.4}\frac{P}{A}$$

where P = perimeter in inches, A = cross-sectional area in square inches, α = absorption coefficient of lining.

DUCTILITY. The property of being ductile, i.e., capable of being drawn out in a wire. It is generally possessed to the greatest degree by certain metals.

DUFFIN-KEMMER MATRICES. Matrices β_μ (μ = 1, 2, 3, 4) satisfying

$$\beta_\mu\beta_\nu\beta_\sigma + \beta_\sigma\beta_\nu\beta_\mu = \delta_{\mu\nu}\beta_\sigma + \delta_{\nu\sigma}\beta_\mu.$$

The equation $\left[\Sigma\beta_\mu\frac{\partial}{\partial x_\mu} + \frac{mc}{\hbar}\right]\psi = 0$ then describes particles of spin 0 or $\hbar$.

DUFOUR EFFECT. Abnormal **Zeeman effect.** Individual lines show Zeeman effect in band spectra, if observed in a direction parallel to field and if circular vibrations are converted into plane ones with a quarter-wave plate, through Nicol prism.

DUHEM-MARGULES EQUATION. A relationship between the partial vapor pressures of a two-component liquid system and the concentration of the constituents:

$$N_A\left(\frac{\partial \ln p_A}{\partial N_A}\right)_{P,T} = N_B\left(\frac{\partial \ln p_B}{\partial N_B}\right)_{P,T}$$

or

$$\frac{d \ln p_A}{d \ln N_A} = \frac{d \ln p_B}{d \ln N_B}$$

where N_A = mole fraction of component A, N_B = mole fraction of component B, p_A = partial pressure of component A, the vapor behaving as an ideal gas, p_B = partial pressure of component B, the vapor behaving as an ideal gas, P = total pressure, T = temperature. This relation may only be applied at constant temperature.

DULONG AND PETIT LAW. The product of the atomic weight and the specific heat of many solid elements (i.e., their atomic heats or thermal capacities) have almost the same value, about 6 calories per °C. Dulong and Petit expressed this relationship by stating that the specific heats of elements are in inverse proportion to their atomic weights. This "law" tends to be obeyed best at high temperatures. (Cf. **Debye theory of specific heats.**)

DUMAS METHOD FOR VAPOR PRESSURE. A small quantity of the liquid the density of whose vapor is required is inserted into a weighed glass bulb which has a neck drawn to a point. The bulb is heated to about 30°C above the boiling-point until the liquid disappears, the vapor being rapidly expelled and carrying the air in the bulb with it. After measuring barometric pressure and temperature of the bath, the bulb is sealed off, cooled, and re-weighed. The end of the neck is then broken off under water, when the water completely fills the bulb. The weight of the bulb is again found, full of water, giving its internal volume. From the readings the weight of a known volume of vapor is found, and hence its density. The method is frequently

used when a more accurate method than the **Victor Meyer method** is required. Modifications have been made at lower pressures and higher temperatures.

DUMMY ANTENNA. See **antenna, dummy.**

DUMMY INDICES. The repeated indices ν, σ, etc., in an expression of the form

$$\sum_{\nu,\sigma,\ \cdot} A_{\mu\nu}B_{\nu\sigma}C_{\sigma\tau}\cdots.$$

The term is used particularly in relativity theory, in which the **summation convention** implies summation over the values 1 to 4 of all dummy indices.

DUMMY LOAD. A dissipative but essentially nonradiating, substitute device.

DUODIODE. See **tube, electronic** for discussion of double diode.

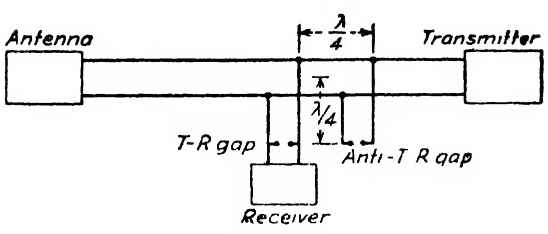
DUO-DIRECTIONAL AMPLIFIER. See **amplifier, push-pull.**

DUOLATERAL COIL. A coil having its conductors wound in a criss-crossed fashion, to reduce winding capacitance.

DUOTRIODE. Two triodes in a single envelope

DUPLET. A pair of electrons that is shared by two atoms and that corresponds to a single valence **bond.**

DUPLEXERS (TRANSMIT-RECEIVE CIRCUITS). Circuits that make possible the use of the same antenna for both transmission and reception, by preventing the flow of damaging amounts of power to the receiver during transmission, without at the same time reducing excessively the input to the receiver during reception. Consider a basic circuit shown below. During reception, the open-circuited,



DUPLEXERS

Basic circuit showing placement of T-R and anti-T-R tubes (By permission from "Microwave Theory and Techniques" by Reich et al, Copyright 1953, D. Van Nostrand Co Inc.)

quarter-wavelength branch containing the anti-T-R tube produces an effective short circuit at the junction of this branch and the transmitter branch, and therefore prevents loss of received power to the transmitter. A quarter of a wavelength away, at the junction of the antenna and receiver lines, this short circuit appears as an open circuit. During transmission, both tubes break down and short-circuit the lines in which they are placed. Since the short circuits occur at a distance of a quarter-wavelength from the transmitter-antenna line, the receiver and anti-T-R lines present an infinite (ideally) impedance across the transmitter-antenna line, and therefore divert negligible power. It is possible to use only the T-R tube but this necessitates careful adjustment of the transmitter-to-junction distance which, in the scheme shown, is not a critical factor. (See **transmit-receive switch.**)

DUSHMAN EQUATION. See **Richardson-Dushman equation.**

DUST CORE. A **magnetic core** composed of pulverized particles bound together by a suitable binder The small particle-size reduces core losses sufficiently to allow use of the cores at much higher frequencies than would otherwise be possible.

DUST DEVIL. Whirlwinds over sandy areas which pick up dust and sand, swirling the particles upward They sometimes become fairly strong and reach hundreds of feet upward.

DUST STORM. Over dusty dry or desert areas strong winds which have picked up considerable dust and carried it to great heights. Sand storms are similar to dust storms. Three factors are necessary in the development of a dust or sand storm: (1) a dusty or sandy surface, (2) strong winds which can strike at the ground and pick up dust particles, and (3) a steep **lapse rate,** i.e., unstable air, which permits the dust to be carried to great heights.

Visibility in dust storms is usually only a few yards and sometimes reduced to night-like darkness.

DUTY CYCLE. (1) The time interval occupied by a device on intermittent duty in starting, running, stopping, and idling (2) The ratio of this time interval to the **total** time of one operating cycle.

DUTY FACTOR. In a **pulse carrier** composed of pulses that recur at regular intervals, the product of the **pulse duration** and the **pulse-repetition** frequency.

DX. Abbreviation used to indicate distance in communication, as between distant stations.

DYADIC. An **operator**, related to a **tensor** of the second rank, which transforms one **vector** into another. Thus

$$\mathfrak{A}\mathbf{B} = \mathbf{C}.$$

The dyadic $\mathfrak{A}$ in n dimensions has n^2 components A_{ij} in the coordinate system $x_1, x_2, \cdots x_n$. The definition of a dyadic requires that the components of $\mathfrak{A}$ in a new coordinate system, $x'_1, x'_2, \cdots x'_n$, be given by

$$(A_{ij})' = \sum_{m,n} \frac{h_m h_n}{h'_i h'_j} \frac{\partial x_m}{\partial x'_i} \frac{\partial x_n}{\partial x'_j} A_{mn}$$

where

$$h_m^2 = \left(\frac{\partial x_1}{\partial x'_m}\right)^2 + \left(\frac{\partial x_2}{\partial x'_m}\right)^2 + \cdots \left(\frac{\partial x_n}{\partial x'_m}\right)^2.$$

Dyadics differ from tensors in the factor involving the scale factors, h_m, etc. Tensors have the factor $h_m h_n$ or $1/h'_i h'_j$ but not both. The advantage of the dyadic form is that its dimensionality does not change upon **transformation,** whereas that of a tensor may change.

A dyadic is often written symbolically as a vector product, the usual dot or cross being omitted. Thus, $\mathfrak{A} = \mathbf{BC}$. The components A_{ik} of $\mathfrak{A}$ are the various products $B_i C_k$ and are therefore homogeneous quadratic functions of the vector components.

Dyadics are used in the study of crystal structure, rotation of bodies in mechanics, and in elastic deformation.

DYKANOL. Trade name for an askarel (chlorinated synthetic) impregnant for paper capacitors.

DYNAMIC BRAKING. See **braking, dynamic.**

DYNAMIC CHARACTERISTIC (OF AN ELECTRON TUBE). See **load characteristic (of an electron tube).**

DYNAMIC COOLING. Decrease in temperature of air when caused by its adiabatic expansion in moving to a higher altitude or other region of lower pressure.

DYNAMIC LOUDSPEAKER. See **loudspeaker, dynamic.**

DYNAMIC MICROPHONE. See **microphone, moving-coil.**

DYNAMIC NOISE SUPPRESSOR. See **noise suppressor, dynamic.**

DYNAMIC PICKUP. A **pickup** utilizing a coil positioned in a constant magnetic field and driven by the stylus.

DYNAMIC POWER GAIN. See **power gain, dynamic.**

DYNAMIC PRESSURE (TOTAL HEAD). The pressure that moving fluid would attain if it were brought to rest by isentropic flow up a pressure gradient. For an incompressible fluid, the dynamic pressure is the sum of the local pressure and the kinetic energy per unit volume.

DYNAMIC SENSITIVITY. See **sensitivity, dynamic.**

DYNAMIC SEQUENTIAL CONTROL. See **sequential control, dynamic.**

DYNAMICAL ANALOGIES. The formal similarities among the differential equations of electrical, mechanical and acoustical systems which make possible the reduction of mechanical and acoustical systems to electrical networks and the solution of such problems by electrical circuit theory.

DYNAMICAL SIMILARITY OF FLUID FLOW. Two geometrically similar fluid flows are dynamically similar if the flow field of one may be transformed into the flow field of the other by the same change of length and velocity scales that was necessary to make the boundary conditions identical. If the equations of motion of the flow are made non-dimensional by expressing velocities and lengths as fractions of these scales, these equations contain a number of non-dimensional coefficients that determine the character of the flow. The general condition for dynamical similarity is that all these coefficients should be the same for the two flows. The coefficients commonly used are the **Reynolds number,** the **Prandtl number,** the **Grashof** (or Rayleigh) **number,** the **Mach number** and the **Froude number.**

DYNAMICS. Of, or pertaining to the description of the motion of systems of particles under the influence of **forces.** Dynamics deals with the causes of motion, as opposed to **kinematics,** which deals with its geometric description, and to **statics,** which deals with the conditions for lack of motion.

DYNAMO. A member of a general class of machines capable of transformation of electrical into mechanical energy, or vice versa. The word is a shortened form of dynamoelectric. A feature of all dynamo machines is the employment of **magnetic induction** in effecting the transformation. The essential parts of an ordinary dynamo are the **armature** and the **field.** One of these is mounted on a rotating shaft, and the other is stationary. In ideal cases, such as d-c dynamos and separately-excited a-c dynamos, the machine is reversible, i e , it may be used as either a motor or a generator.

DYNAMOELECTRIC AMPLIFIER. See **amplifier, dynamoelectric.**

DYNAMOMETER. An instrument for measuring force, such as a spring balance. Most writers, however, apply the term to certain devices for the measurement of mechanical power. The principal classification is derived from the fact that some types of dynamometers absorb all of the power, which is converted into heat, whereas others transmit the power they receive to some other absorber of power, measuring it during the process. These are called, respectively, absorption and transmission dynamometers.

In the absorption dynamometer class there are types which convert the mechanical to heat energy through the medium of mechanical friction. They are all similar to the Prony brake. (See **brake horsepower.**) The friction surfaces are variously wooden blocks against metal drums or pulleys, bands with wooden cleats, ropes, or friction-surfaced brake bands. Also there are hydraulic dynamometers which absorb the power by fluid friction. One common arrangement is similar to a centrifugal pump, except that the casing, instead of being rigidly fixed to a bed plate, is freely supported on the propeller shaft. It is restrained from rotating by an attached arm. The restraining moment in the brake arm is measured by platform or spring scales. The energy absorbed appears as a heating of the water in the dynamometer. To prevent it boiling it must be steadily renewed. Thus the energy is carried off in a stream of water entering the dynamometer cool and leaving warm. Air friction has also been set to use in the fan brake absorption dynamometers.

One of the most convenient means for measuring power is to convert it to electrical power (watts). In an electrical dynamometer a **generator** is slightly modified. The stator is mounted, free to revolve, but restrained from revolving by a brake arm which is attached to it, and to which are fastened weighing scales. The tendency of the casing to rotate with the rotor which is connected to the source of the power is opposed by the brake arm. The force shown on the scales becomes a **torque** when multiplied by its lever distance from the center of rotation. Since power is torque multiplied by rotative speed, the only other reading necessary from the dynamometer is the speed of the rotor shaft. In all absorption dynamometers the casing is mounted free to revolve under the action of mechanical friction, fluid friction, or magnetic drag. Actual rotation is prevented by the attached brake arm. Power is measured as a torque operating at the rotative speed of the driven shaft.

A transmission type dynamometer is illustrated by the torsion type, in which a shaft delivering power is twisted through a small angle by the torque. Such a shaft may be calibrated at rest by measuring the torsional deflection obtained under known torque loadings This dynamometer has its greatest field of usefulness where the other types are impractical Measurement of power output from a large marine engine is typical.

DYNAMOTOR. A double-**armature** rotating electrical machine. One of the armatures is wound for low voltage direct current, and serves as a motor armature. The other armature is wound for a high d-c voltage and serves as a generator winding The machine is used for supplying plate voltage to portable radio equipment, being operated from storage batteries on the motor end and supplying the high voltage d-c from the generator winding

DYNATROL. Trade name for a solenoid-operated **control motor.**

DYNATRON. This term is applied to a vacuum **tube** operated in such a manner that

its plate characteristic has a negative resistance section, i.e., the plate current increases while the plate voltage decreases. The most common application is for stable **oscillators.** The screen-grid or tetrode vacuum tube exhibits this characteristic when the screen voltage is higher than the plate voltage.

DYNATRON OSCILLATOR. See **oscillator, dynatron.**

DYNETRIC BALANCING. An electronic method of balancing rotating parts. The test apparatus can locate and measure the degree of unbalance.

DYNODE. (1) An additional electrode in a **photomultiplier tube,** which undergoes **secondary emission** upon bombardment by **photoelectrons,** and thus effects **amplification.** (2) A photo-multiplier tube having one or more dynodes (1).

DYNODE CURRENT. See **electrode current.**

DYOTRON. A microwave oscillator tube (see **tube, microwave oscillator**) containing a single cavity and three electrodes.

DYSPROSIUM. Rare earth metallic element. Symbol Dy. Atomic number 66.

DYSTECTIC MIXTURE. A mixture of two or more substances in such proportions as to yield the maximum melting point, so that upon altering the proportions the melting point is lowered. Correlative of **eutectic mixture.**

E

E. (1) Symbol for an electron or its electric charge (e). (2) The number e (see **e, the number**), the natural logarithmic (Napierian) base (e). (3) Electromotive force ($\mathcal{E}$ or E). (4) Electrode potential ($\mathcal{E}$ or E). (5) The Einstein, a unit of energy (E). (6) Total energy (E). (7) Kinetic energy (E_k). (8) Potential energy (E_p). (9) Energy of vibration (E_v). (10) Electric field strength (**E**). (11) Illuminance (E). (12) Young's modulus of elasticity (E). (13) Coefficient of resilience or restitution (e). (14) Radiant flux density ($\mathcal{E}$). (15) In spectroscopy, enhanced at electrode (e), enhanced in spark as compared with arc (E).

***e*, THE NUMBER.** A **transcendental number,** used as the base of the system of **natural** or **Napierian logarithms.** It is defined by

$$e = \lim_{n \to \infty} \left(1 + \frac{1}{n}\right)^n$$

or by

$$e = \lim_{x \to 0} (1 + x)^{1/x}.$$

It is represented by the infinite series

$$e = 1 + \frac{1}{1!} + \frac{1}{2!} + \frac{1}{3!} + \frac{1}{4!} + \cdots + \frac{1}{n!} + \cdots$$

and has the approximate value of 2.71828.

E LAYER. An ionized layer in the **E region.**

E-LINES. A contour representing a constant electrostatic field strength with respect to some reference plane.

E-PLANE BEND. For a rectangular uniconductor **waveguide** operating in the **dominant mode,** a bend in which the longitudinal axis of the guide remains in a plane parallel to the electric field vector throughout the bend.

E-PLANE TEE JUNCTION. See **junction, E-plane tee.**

E REGION. The region of the **ionosphere** between about 90 and 160 kilometers above the **earth's surface.**

EAGLE MOUNTING. A method of mounting a **diffraction grating** so as to use the diffracted light, which is returned back along nearly the same path as the incident beam.

EARNSHAW THEOREM. No charge can be in stable equilibrium in an **electric field** under the influence of electric forces alone.

EARPHONE (RECEIVER). An electroacoustic transducer (see **transducer, electroacoustic**) intended to be closely coupled acoustically to the ear. The term "receiver" should be avoided when there is risk of ambiguity.

EARPHONE COUPLER. A cavity of predetermined shape which is used for the testing of **earphones.** It is provided with a **microphone** for the measurement of pressures developed in the cavity.

EARPHONES, INSERT. Small **earphones** which fit partially inside the ear.

EARTH, EFFECTIVE RADIUS OF THE. An effective value for the radius of the earth, which is used in place of the geometrical radius to correct for atmospheric refraction when the index of refraction in the atmosphere changes linearly with height. Under conditions of standard refraction, the effective radius of the earth is 8.50×10^6 meters, or $\frac{4}{3}$ of the geometrical radius.

EARTH, FIGURE OF THE. The exact shape and size of the earth, as determined by terrestrial surveys in conjunction with the observation of celestial bodies from various points on the surface, or in conjunction with measurements of the **acceleration due to gravity.** The earth is approximated closely by an oblate spheroid, with an equatorial radius of 6.378×10^6 meters and a polar radius of 6.357×10^6 meters

EARTH INDUCTOR. A coil rotated in the earth's magnetic field to permit determination of the **field's strength.**

EARTH INDUCTOR COMPASS. An induction compass. (See **compass, induction.**)

EARTHED. See **grounded.**

EBERHARD EFFECT. Eberhard gave a photographic plate a uniform exposure through a metal plate with openings of various sizes and found that the density of the exposed areas varied, the density decreasing with the size of the area. The amount of the variation in density increases with the thickness of the emulsion coating and is decreased by an exposure of the background or by general fog. The effect is produced by all organic developers but not by ferrous oxalate and is considered to be due to the effect of the accumulation of restraining by-products of the process of development. The Eberhard effect is a factor affecting the fidelity of photographically recorded sound, and the accuracy of the photographic image in astrophysical and photometric investigations.

EBULLIOSCOPE. Any instrument that measures a property by a deviation from a normal known **boiling point.** Thus this term is applied to an apparatus in which the percentage of alcohol in a mixture is estimated by an observation of the boiling point. **Beckmann's apparatus** for molecular weight determination is an ebullioscope.

EBULLIOSCOPIC CONSTANT. A quantity calculated to represent the molal elevation of the boiling point of a solution, by the relationship:

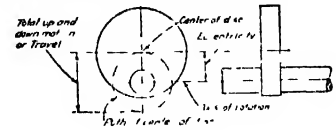
$$K = \frac{RT_o^2}{1000l_e}$$

in which K is the ebullioscopic constant, R is the **gas constant,** T_o is the boiling point of the pure solvent, and l_e is the **latent heat of evaporation** per gram. The product of the ebullioscopic constant and the **molality** of the solution give the actual elevation of the boiling point for the range of values for which this relationship applies. Unfortunately, this range is limited to very dilute solutions, not extending to solutions of unit molality.

EBULLISCOPY. Determination of molecular weight by measurement of elevation of boiling point.

EBULLITION (BOILING). The vaporization of a liquid due to the escape of bubbles of its vapor formed where heat is applied below the surface.

ECCENTRIC. A machine element employed to convert rotating to reciprocating motion. Its function is similar to that of the crank. The eccentric is used chiefly for short throws, where it would be undesirable to break the shaft, as is necessary in the case of a crank. It consists of a disk mounted on a shaft in such a way that the geometric center of the



Simple eccentric

disk does not coincide with the center of rotation. The distance between the center of rotation and the geometric center of the eccentric is the throw. This corresponds to the crank-arm distance of an equivalent crank. The eccentric is chiefly used to drive auxiliaries such as valve gear, and where reciprocation of small magnitude is needed. The cam and crank may be employed to provide similar motion.

ECCENTRIC ANOMALY (CELESTIAL MECHANICS). The eccentric anomaly E is the arc cosine $(a - r)/a\epsilon$ where a is the semi-major axis of an elliptical planetary orbit, r is the radius vector from the focus to the path, and ϵ is the eccentricity of the ellipse. E appears in the Kepler equation $M = E - \epsilon \sin E$, where M is the mean anomaly. The solution of the Kepler equation with a given value of M permits E and hence r to be determined.

ECCENTRIC CIRCLE. The unmodulated, endless groove provided at the inside of most phonograph records. Its center differs from that of the record, to facilitate the actuation of the trip mechanisms of some types of automatic record changers.

ECCENTRIC SPIRAL. The unmodulated spiral groove which leads from the end of the modulated groove portion of a phonograph record to the **eccentric circle.**

ECCENTRICITY. See **conic section.**

ECCLES-JORDAN CIRCUIT. See **circuit, Eccles-Jordan.**

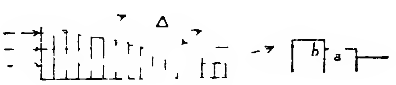
ECHELETTE GRATING. A **diffraction grating** in which the lines, grooves, have been shaped so as to concentrate much of the radia-

tion of a given wavelength into one particular order. Particularly useful in the infrared portion of the spectrum.

ECHELLE GRATING. In studies of high resolution **diffraction gratings,** it is observed that resolving power at a given wavelength depends only on the ruled width of the grating and the angles of illumination and observation, and not specifically on the number of ruled grooves. The ruling of many inches of a grating with a few tens of thousands of lines per inch is an almost impossible task. An echelle grating has very fine lines ruled much farther apart than is customary. Such a grating has very high **resolution,** but over only a quite narrow band of wavelengths. Hence it is customary to cross an echelle grating with a second grating (or prism) of lower **resolving power,** thus producing what is essentially a two-dimensional spectrogram or **echellegram.**

ECHELLEGRAMS. Spectra on a photographic plate caused by an **echelle grating.**

ECHELON. A highly specialized form of **diffraction grating,** devised by Michelson. It consists of a row of glass plates of exactly



Echelon

equal thickness, packed together to form a miniature stairway of equal risers. The light enters normally to the largest plate at one end (see figure) and emerges at various deviations through the low "risers."

The echelon may also be used as a reflection instrument, the light being reflected from the steps. With 40 plates, a resolving power over 10^6 may be obtained, a resolving power rivaled only by the Fabry-Perot etalon and the Lummer-Gehrcke plate.

ECHO. A wave which has been reflected at one or more points in the transmission medium, or otherwise returned with sufficient magnitude and delay to be perceived in some manner as a wave distinct from that directly transmitted.

ECHO DEPTH SOUNDING. The determination of the depth of water by the measurement of the time interval required for a sonic or supersonic pulse to reach the transmission point after being reflected from the bottom.

ECHO, FLUTTER. A rapid succession of reflected pulses resulting from a single initial **pulse.**

ECHO LEVEL.

$$E = 10 \log \frac{I_e}{I_r}$$

where E = echo level in decibels, I_e = intensity of returning sound signal, I_r = reference intensity.

ECHO, MUSICAL. A flutter echo (see **echo, flutter**) that is periodic and has a flutter whose frequency is in the audible range.

ECHO RANGING. The determination of the distance and direction of underwater objects by the same process used in **echo depth sounding.** Commonly called **sonar.**

ECHO SUPPRESSOR. When an electric wave on a **line** encounters a discontinuity or point at which the impedances do not match (see **impedance matching**) some of it is reflected. This reflected wave may return to the sending end of the line with sufficient amplitude to be objectionable. This is especially true in telephone service. While an effort is made to prevent reflections, there are cases where energy is fed back along the line and returns to the sender as an echo. In certain systems two lines (4 wires) are employed for transmission in the two directions and in such systems echo suppressors may be used to suppress the returning wave. This is accomplished by using a relay to short one line when there is a signal on the other. Thus if party A is talking and sending a voice signal to B, the voice currents on the line from A to B operate a shorting relay across the line from B to A so party A does not receive his own voice as an echo.

ECHOES, TYPES OF NATURAL. These include: (1) The discrete single echo. (2) The discrete multiple echo (a number of successive reflections). (3) The overlapping multiple echo -**reverberation.** (4) The diffuse echo, due to the scattering of sound by many small objects. (5) The harmonic echo, due to the greater scattering of an overtone than of the fundamental. (6) The musical echo, due to reflection from, or scattering by, a

series of objects spaced at uniformly increasing distances from the source.

ECO. Abbreviation for **electron-coupled oscillator.**

EDDINGTON THEORY. Theory proposed by A. S. Eddington to describe the observed values of the proton-electron mass ratio, the **fine structure constant**, and other dimensionless ratios Based primarily on the idea that in describing a physical system it is not legitimate to ignore the presence of the rest of the universe. It has not yet been possible to put the theory into a precise form.

EDDY CURRENT(S). Currents set up in a substance by variation of an applied magnetic field. (See **Maxwell equations.**) Eddy currents result in both power loss and reduction of magnetic flux. Transformer cores and dynamo frames are laminated to break up the iron structure into thin, insulated layers, to reduce eddy currents. Eddy currents are used in induction heating and in various **damping** devices

EDDY-CURRENT ENERGY. The energy lost due to eddy currents. (See **current, eddy.**)

EDGE DISLOCATION. See **dislocation, edge.**

EDGE EFFECT. In a **capacitor** comprising two parallel plates, the **electric field** is normal to the plates except near the edges, where the field lines bulge outward This edge effect introduces a correction to the capacitance as computed from the parallel field idealization. By giving one plate greater area than the other, and surrounding the smaller plate with an auxiliary guard ring maintained at the potential of the smaller plate, the edge effect is eliminated, and the capacitance between the small plate and the large plate is given by the simple theory.

EDGE TONES. The **tones** produced by the splitting of an air-jet by a sharp edge maintained in the jet.

EDSER-BUTLER METHOD OF CALIBRATING A SPECTROMETER. By passing light through an **etalon** of known thickness and then into a **spectrometer,** the **interference** bands may be used to determine a curve giving the relation between wavelength and position in the spectrum. This method was discovered by Fizeau and Foucault (1850), used by Esselbach (1885), but brought into common use by Edser and Butler (1896).

EFFECTIVE ACOUSTIC CENTER. See **acoustic center, effective.**

EFFECTIVE AREA (ANTENNA). The square of the wavelength times the **power gain** (or **directive gain**) in a specified direction, and divided by 4π. When power gain is used, the effective area is that for power reception; when directive gain is used, the effective area is that for **directivity.**

EFFECTIVE BAND WIDTH. See **band width, effective.**

EFFECTIVE CUTOFF FREQUENCY. See **cutoff frequency, effective.**

EFFECTIVE ANGULAR VELOCITY. The effective angular velocity at a point is the root mean square value of the instantaneous **angular velocity** over a complete cycle at the point. The unit is the radian per second.

EFFECTIVE FORCE (EFFECTIVE MECHANOMOTIVE FORCE). The root mean square of the instantaneous force (see **force, instantaneous**) over a complete cycle. The unit is the dyne.

EFFECTIVE HEIGHT (ANTENNA). In its former usage, this term was applied to the actual height of the vertical section, multiplied by the ratio of the average current in that section, to the input current. In its present usage, this term means the height of the antenna center of radiation above the effective ground level. For an antenna with symmetrical current distribution, the center of radiation is the **center of distribution.** For an antenna with asymmetrical current distribution, the center of radiation is the center of current moments when viewed from directions near the direction of maximum radiation.

EFFECTIVE MASS. A parameter of the dimensions of a mass which is often used in the **band theory of solids.** An exact definition covering all its uses is impossible, but one may say that electrons at the bottom of a band, and **holes** near the top of a band, behave in many respects as if they were free particles with masses rather different from the mass of a free electron.

EFFECTIVE MOBILITY OF IONS. See **ions, effective mobility of.**

EFFECTIVE PERCENTAGE MODULATION. See **modulation, effective percentage.**

EFFECTIVE POWER OF A LENS. The reciprocal of the **back focal length.**

EFFECTIVE SOUND PRESSURE. See **sound pressure, effective.**

EFFECTIVE VALVE (OF AN ELECTRICAL QUANTITY). The root-mean-square of the current, potential difference, or power in an electrical circuit in which the current is alternating or otherwise varying with time. The effective value of a quantity which varies sinusoidally is $1/\sqrt{2}$ times the **amplitude.**

EFFECTIVE VELOCITY. The effective velocity at a point is the root mean square value of the instantaneous **velocity** over a complete cycle at that point. The unit is the centimeter per second

EFFECTIVE WAVELENGTH. The wavelength of a monochromatic beam having the same **penetration** in a given medium as a beam of ordinary light.

EFFICIENCY. The general significance of this term as applied to a device or machine in which either a transfer of energy from one place to another, or a transformation of energy from one form to another occurs, may be expressed as the ratio of useful output to total input of energy or of power. The ratio is customarily expressed as a percentage. If a d-c motor, for example, is operating on 4 amperes at 100 volts (the power input is 400 watts), and if the motor actually delivers only 280 watts of mechanical power, its efficiency at that load is 280 watts ÷ 400 watts, or 70 per cent. In general, the efficiency of a machine varies somewhat with the conditions under which it operates. Usually there is a load for which the efficiency is a maximum. This may be illustrated by a heavy block-and-tackle. For a small load the efficiency would be very low, because of power wasted in bending the ropes; for an excessive load it would again be low, on account of the large friction which would then develop; while for intermediate loads, higher efficiencies would prevail.

The concept may be extended to other than purely mechanical systems. Thus, the efficiency of an electric lamp may be expressed in candles or lumens of luminous flux (output) per watt of electric power (input); or that of an automobile horn in watts of acoustic power (noise) per watt of electric input. Various types of heat engine exhibit different thermodynamic efficiencies, i.e., the ratio of the work derived in the engine to the heat energy applied to it. (See **thermal efficiency.**)

EFFICIENCY, QUANTUM. See **quantum efficiency.**

EFFLORESCENCE. The property of hydrated salts (i.e., chemical compounds of salts with water) whereby they lose some or all of their water of crystallization to the atmosphere. The necessary condition is that the water-vapor pressure of the salt is greater than the partial pressure of water vapor in the atmosphere. The process continues until the vapor pressure of the salt is nearly equal to the partial pressure of the water in the atmosphere.

EFFUSIOMETER. Any instrument measuring rates of effusion of material from an orifice

EFFUSION. A general term denoting a process of discharge, that is also used specifically to denote the passage of a gas under pressure through a small orifice. This process is also called diffusion (See **Graham law.**)

E-H TEE. A **junction** composed of a combination of E and H-plane **tee junctions** having a common point of intersection with the main guide.

E-H TUNER. An **E-H tee** used for impedance transformation, having two arms terminated in adjustable plungers.

EHRENFEST ADIABATIC LAW. For a virtual and infinitely slow alteration of the coupling conditions, the quantum numbers of the atomic system do not change, and the number of terms also does not change.

EIGENFUNCTION. If a **differential** or **integral equation** possesses solutions satisfying the given boundary conditions for only certain values of a parameter λ, such a value of λ is an **eigenvalue** (proper or characteristic value) and the corresponding solution is the

eigenfunction belonging to λ. Thus, given the **linear operator** P, the solutions u to the equation $Pu = \lambda u$ are eigenfunctions of P belonging to the eigenvalue λ. The totality of eigenfunctions of any linear operator constitute the **complete set**, which may be made **ortho normal.**

EIGENSTATE. If $\psi(\mathbf{r},t)$ represents the state of a physical system, ψ is an eigenstate of the operator A, representing the measurement of some physical property of the system, if $A\psi = a\psi$ where a is a number.

EIGENVALUE. (1) See **eigenfunction.** (2) If λ is a scalar parameter, $\mathbf{A}$ a square **matrix** of order n, and $\mathbf{E}$ the unit matrix of the same dimension, then $\mathbf{K} = |\lambda\mathbf{E} - \mathbf{A}|$ is the **characteristic matrix** of $\mathbf{A}$. The equation $det\ \mathbf{K} = 0 = \lambda^n + a_1\lambda^{n-1} + \cdots + a_n$, where the a_i are functions of the elements of $\mathbf{A}$, is the **characteristic equation** of $\mathbf{A}$ and its roots are the **eigenvalues** or characteristic roots. The **trace** of $\mathbf{A}$ is the sum of the eigenvalues. Two matrices related by a **similarity transformation** have the same eigenvalues and hence the same trace. (3) See **integral equation.**

EIGENVECTOR. An **eigenfunction,** regarded as a **vector** in an abstract space.

EIGHT BALL. A spherically-shaped, nondirectional **microphone.**

EIKONAL EQUATION. The fundamental equation determining the path of a **ray:**

$$|\nabla W|^2 = n^2(x,y,z),$$

where n is the index of refraction for the waves and $W(x,y,z)$ is a function defining the wave fronts of the wave.

EIKONOMETER. A scale, attached to the eyepiece of a **microscope,** which is seen superimposed on the image, and is used to measure the dimensions of the objects viewed.

EINSTEIN-BOSE STATISTICS. See **Bose-Einstein statistics.**

EINSTEIN COEFFICIENTS. Discussed under **Einstein transition probabilities.**

EINSTEIN-DE HAAS METHOD. A technique for measuring the **gyromagnetic effect** by reversing the magnetization of a freely suspended specimen and observing the resulting rotation.

EINSTEIN DIFFUSION EQUATION. An equation for the mean square displacement of spherical colloidal particles in a gas or liquid, due to **Brownian movement.** The mean square displacement from its original position after a time τ is

$$\overline{x^2} = \frac{RT}{3\pi\eta rN}\tau,$$

where R is the gas constant, T is the absolute temperature, r is the radius of the particle, η is the viscosity, N is Avogadro's number. This relationship is only valid for particles of such size that they obey **Stokes'** resistance **law.**

EINSTEIN EQUATION FOR HEAT CAPACITY. A **quantum** relationship for the heat capacity at constant volume of an element of the form:

$$C_v = 3R\left(\frac{h\nu}{kT}\right)^2\left(\frac{e^{h\nu/kT}}{(e^{h\nu/kT} - 1)^2}\right)$$

in which C_v is the **heat capacity** at constant volume for one gram-atom of an element, R is the **gas constant,** h is **Planck's constant,** k is the **Boltzmann constant,** ν is the **characteristic frequency** of oscillation of the atoms of the element, T is the absolute temperature, and e is the natural logarithmic base.

The Einstein equation was the first approximation to a quantum theoretical explanation of the variation of specific heat with temperature. It was later replaced by the **Debye heat capacity equation** and its modifications.

EINSTEIN FORMULA FOR MASS-ENERGY EQUIVALENCE. The equivalence of a quantity of mass m and a quantity of energy E by the formula $E = mc^2$. (See **mass-energy equivalence.**)

EINSTEIN LAW OF GRAVITATION. The equation $R_{\mu\nu} = -8\pi T_{\mu\nu}$ where $T_{\mu\nu}$ is the energy momentum tensor and $R_{\mu\nu} = G_{\mu\nu} - \frac{1}{2}g_{\mu\nu}G$ is the **contracted Riemann-Christoffel tensor,** G is the **curvature.** In empty space the law becomes $G_{\mu\nu} = 0$. (See **cosmological constant.**)

EINSTEIN LAW OF PHOTOCHEMICAL EQUIVALENCE. See **Stark-Einstein law.**

EINSTEIN PHOTOELECTRIC EQUATION. An equation giving the kinetic energy of an electron ejected from a system in the

photoelectric effect, where the electron is ejected by an incident photon, absorbing all the energy of the latter. This equation is:

$$E_k = h\nu - \omega$$

where E_k is the kinetic energy of the ejected electron, h is the Planck constant, ν is the frequency associated with the absorbed photon, and ω is the energy necessary to remove the electron from the system.

EINSTEIN RELATIONSHIP BETWEEN MOBILITY AND DIFFUSION CONSTANT. The **mobility** μ of charges in a **semiconductor,** or **ionic solution** is related to the **diffusion coefficient** D by

$$\mu = eD/kT$$

where e is the magnitude of the charge, k is the **Boltzmann constant,** and T is the absolute temperature.

EINSTEIN SHIFT. A shift toward the red in the spectral lines of light, this shift resulting from a slight reduction in frequency of the light as it emerges from a strong gravitational field, such as that of a dense star.

EINSTEIN SPECIFIC HEAT FUNCTION. The heat capacity of an assembly of N simple harmonic oscillators, all having the same frequency is given by

$$C = Nk(h\nu/kT)^2 e^{h\nu/kT}/(e^{h\nu/kT} - 1)^2,$$

where h and k are the **Planck** and **Boltzmann constants.** This type of function represents the contribution of the **optical modes** to the specific heat of a solid, which is otherwise more accurately given by a **Debye function.**

EINSTEIN TRANSITION PROBABILITIES. In Einstein's derivation of the Planck equation for black body radiation three coefficients were introduced which are of importance in the consideration of spectral intensities. Assume two quantum states m and n of a system such that the energy level E_m is higher than E_n; then transition from the upper to the lower state is accompanied by emission of radiation of frequency

$$\nu_{mn} = \frac{E_m - E_n}{h}.$$

Assume further that there are a large number of identical systems (atoms or molecules) in equilibrium with black body radiation at a temperature T. Then the rate at which systems pass spontaneously from state m to n, by emission of radiation, is given by

$$-\left(\frac{dN_m}{dt}\right)_1 = A_m{}^n N_m,$$

where $A_m{}^n$ is known as *Einstein's coefficient of spontaneous emission,* and N_m is the number of systems in state m. But the rate at which systems can pass from the upper to lower state is also dependent upon the density of the radiation, $\rho(\nu_{mn})$, so that there is a second process defined by the relation,

$$-\left(\frac{dN_m}{dt}\right)_2 = B_m{}^n N_m \rho(\nu_{mn}),$$

where $B_m{}^n$ is known as *Einstein's coefficient of induced emission.*

Furthermore, the system can pass from the lower to the upper state by absorption of radiation, and the rate of this reaction will be given by

$$-\left(\frac{dN_n}{dt}\right)_2 - B_n{}^m N_n \rho(\nu_{mn})$$

where N_n - number of systems in quantum state n, and $B_n{}^m$ is known as *Einstein's coefficient of absorption.*

EINSTEIN UNIFIED FIELD THEORIES. A series of attempts by Einstein, between 1931 and 1948, to obtain a unified theory of **gravitation** and **electromagnetism.** These represented his dissatisfaction with the indeterminacy of quantum theory, and his search for a unifying principle more general than those which he had discovered in general and special relativity theory (see **relativity, general theory,** and **relativity, special theory**). One attempt (Einstein and Mayer, 1931) was a generalization of **Kaluza theory** based on a five-dimensional tensor calculus of functions which depended on only four dimensions. A later theory (Einstein, Bargmann and Bergmann, 1941) was based on a five-dimensional continuum with the hope that it would lead to indeterminacy when expressed in terms of four dimensions. A third theory (1948) was based on a complex but **Hermitean metric,** the real part of which described the gravitational potentials, the imaginary part describing the electromagnetic field strengths. General arguments by Johnson (1953) indicate that this theory is in-

consistent with the laws of **Newton** and of **Coulomb,** although Einstein believed that such general arguments were not applicable.

EINSTEIN UNIT. A photochemical unit quantity defined under the heading **Stark-Einstein equation.**

EINSTEIN UNIVERSE. Model of the universe in which the interval between two events is given by

$$ds^2 = c^2dt^2 - r^2(d\theta^2 + \sin^2 \theta d\phi^2) - \frac{dr^2}{1 - r^2/R^2}$$

where R is the radius of the universe. The model may be regarded as a four-dimensional cylindrical surface embedded in five-dimensional space.

EINSTEIN VISCOSITY EQUATION (FOR SOLS). For a suspension of rigid spheres

$$\eta_{sp} = \frac{\eta}{\eta_0} - 1 = 2.5\phi$$

where η_{sp} is the **specific viscosity,** η_0 is the **viscosity** of pure solvent, and ϕ is the volume fraction of the disperse phase, and is equal to the volume of the spheres (or particles), divided by the total volume.

In the derivation the following assumptions are made:

1. The radii of the spheres are large compared with those of the solvent, but small compared with the dimensions of the apparatus.
2. The distance between the spheres is large compared with their radius, i.e., the volume concentration of the particles is small.
3. The effects of gravitation and inertia are negligible.

EINSTEINIUM. See **Element #99.**

ELASTANCE. The reciprocal of **capacitance,** measured in **darafs.**

ELASTIC AFTER-EFFECT OR LAG. The time delay which some substances exhibit in returning to original shape after being stressed within their **elastic limits.** There is some evidence that the magnitude of this time depends on the homogeneity of structure of the substance. For instance, quartz which has a homogeneous structure, shows almost no lag. Glass, which is a mixture of aggregates, can have a time delay of the order of hours.

ELASTIC AXIS. See **flexure.**

ELASTIC COEFFICIENTS, LATTICE THEORY OF. The **elastic constants** and **elastic moduli** of crystals may be calculated on the assumption that the only forces are those between near neighbors in the lattice. Such a calculation gives reasonable results for **ionic crystals,** but is quite unsatisfactory for metals, where the **Cauchy relations** are not obeyed. The **free electron gas** in a metal is not easily compressed but scarcely opposes **shear.**

ELASTIC COLLISION. See **collision, elastic.**

ELASTIC CONSTANTS (ALSO KNOWN AS COMPLIANCE CONSTANTS). The coefficients of the relations by which the components of the elastic **strain** are expressed as linear functions of the **stress** components. In general there are 21 different coefficients, but the number may be reduced by the **crystal symmetry** of the solid. (See also **Voigt notation.**)

ELASTIC CURVE. The curve of the neutral surface of a structural member subjected to **loads** which cause bending is called the elastic curve. The ordinates between this curve and the original position of the neutral surface represent the **deflections** due to bending.

ELASTIC HYSTERESIS CONSTANT. The ratio of the area (expressed in energy units) of the **stress-strain loop,** for a unit volume of the material, to the square of the maximal strain.

ELASTIC LIMIT. The maximum unit **stress** which can be obtained in a structural material without causing a permanent **deformation** is called the elastic limit.

ELASTIC MODULI (OR STIFFNESS CONSTANTS). The coefficients of the relations by which the components of **stress** are expressed as linear functions of the components of the elastic **strain.** The number of these depends on the crystal symmetry of the material. (See also **Voigt notation.)**

ELASTIC SCATTERING. See **scattering, elastic.**

ELASTICITY. The property whereby a body, when deformed, automatically recovers its normal configuration as the deforming

forces are removed. Each of its several types is probably due to the action of intermolecular forces which are in equilibrium only for certain configurations.

Deformation or, more briefly, strain is of various kinds; in each case its measure is a certain abstract ratio. For example, the elongation of a rod under tension is expressed as the ratio of the increase in length to the unstretched length. Linear compression is the reverse of elongation. They are both accompanied by a fractional change in diameter, the ratio of which to the elongation is called the Poisson ratio. Shear is a strain involving change of shape, such that an imaginary cube traced in the unstrained material becomes a rhombic prism. The measure of shear is the tangent of the angle through which the oblique edges have been made to depart from their original perpendicular direction. Volume strain is the ratio of a decrease in volume to the normal volume. **Flexure** or bending, and torsion or twisting, are combinations of these more elementary strains. A straight rod bent into a plane curve undergoes elongation on the convex side and linear compression on the concave side, while there is an intermediate neutral layer which suffers neither.

For every strain there arises, in an elastic substance, a corresponding stress, which represents the tendency of the substance to recover its normal condition. Stress is expressed in units of force per unit area. Tensile stress, for example, is the ratio of the force of tension to the normal cross-section of the rod subjected to it. Shearing stress is the force tending to push one layer of the material past the adjacent layer, per unit area of the layers. Pressure, expressed in like units, is the stress corresponding to volume compression, etc.

For each type of strain and stress there is a modulus, which is the ratio of the stress to the corresponding strain. In the case of elongation or linear compression, it is commonly called the **Young modulus**; we also have the **bulk modulus** and the **shear modulus** or rigidity.

In engineering design the **Young modulus** is used for tension and compression and the rigidity modulus for shear, as in torsion springs. (See **Hooke law.**)

ELECTRALLOY. An alloy of iron frequently used for chassis or panels in electronic equipment.

ELECTRET. A permanently-**polarized** piece of **dielectric** material; the analog of a **magnet.** Barium titanate ceramics, preferably containing a small percentage of lead titanate, can be polarized by cooling from a temperature above the **Curie point** in an applied electric field. Electrets are also produced by solidification of mixtures of certain organic waxes in a strong electric field.

ELECTRIC AND MAGNETIC DOUBLE REFRACTION. In 1875 Kerr discovered that glass and many other isotropic, transparent solids and liquids exhibit **double refraction** like crystals, when placed in a strong electric field; and in 1905 Cotton and Mouton, after some preliminary results by Kerr and others, demonstrated the corresponding phenomenon with a magnetic field. These are now known respectively as the Kerr electro-optical effect and the Cotton-Mouton effect. In both cases the magnitude of the effect, as measured by the phase difference produced per unit thickness of medium, is, for a given substance, wavelength, and temperature, proportional to the square of the field intensity. The optic axis of the doubly refracting substance corresponds to the direction of the imposed field.

Of the two phenomena the Kerr effect is much more pronounced and is as yet the only one of practical importance The Kerr cell, in which nitrobenzene, a liquid, is commonly employed because of its large and quick response to the electric field, has in recent years been extensively used as an electro-optical control or shuttter for light beams, for example, in the recording of sound pictures. Recently, ferrites have been used to rotate the **plane of polarization** of microwaves, in the presence of a magnetic field.

ELECTRIC(AL) AXIS. The axis of a crystal which offers minimum resistance to the passage of current.

ELECTRIC(AL) BRIDGE. See **bridge, electrical.**

ELECTRIC(AL) CONDUCTIVITY, THEORY OF. See **conductivity, electrical.**

ELECTRIC CONSTANT. (Symbol ϵ_0 or γ_e.) The electric constant pertinent to any system of units is the scalar dimensional factor ϵ_0 appearing in the **Coulomb law of force** between two charges in vacuo:

$$F = q_1 q_2 / n\epsilon_0 r^2$$

where $n = 1$ for unrationalized units, and $n = 4\pi$ for rationalized units.

In the **esu system,** ϵ_0 is assigned the value unity, with no dimensions In all systems, $\epsilon_0\mu_0 = 1/c^2$, where c is the velocity of light in the appropriate system. Note that c is dimensional. (See **magnetic constant.**) In the **mksa system,** ϵ_0 has the dimensions: farad/meter.

ELECTRIC DEGREE. See **degree.**

ELECTRIC DEPOSITION. See **deposition, electric.**

ELECTRIC DEPTH FINDER. See **sonar.**

ELECTRIC DIPOLE. A pair of equal and opposite charges usually a small distance apart. In electromagnetics, the term "dipole" is often applied to two equal and opposite oscillating charges usually a small distance apart; in this sense, it is synonymous with an electric current element (See also **dipole** and **dipole moment.**)

ELECTRIC DISPERSION. See **dispersion, electric.**

ELECTRIC DISPLACEMENT DENSITY. See **electric flux density.**

ELECTRIC DOUBLE LAYER. See **double layer, electric.**

ELECTRIC EYE. (1) Colloquial name for any type of **photoelectric** or **photovoltaic cell.** (2) Colloquial name for the cathode ray tuning indicator used on some radio receivers.

ELECTRIC FEEDBACK. In **magnetic amplifier** terminology, **feedback** through an electrically conductive network, as differentiated from feedback produced by currents in windings having coupling to the control windings (magnetic feedback).

ELECTRIC FIELD. See discussion of **electromagnetic field.**

ELECTRIC FIELD STRENGTH. The magnitude of the **electric field vector.** This term is sometimes called the electric field intensity, but such use of the word intensity is deprecated in favor of field strength, since intensity connotes power in optics and radiation.

ELECTRIC FIELD VECTOR. At a point in an **electric field,** the force on a stationary positive charge per unit charge. Under conditions in which the ratio of force to charge is not constant, the field vector is defined as the limit of the ratio as the change approaches zero. This may be measured in **newtons** per coulomb, in volts per meter or in corresponding units in systems other than the **mksa system.** (See **Introduction.**) This term is sometimes called the electric field intensity, but such use of the word intensity is deprecated in favor of field strength since intensity connotes power in optics and radiation.

ELECTRIC FLUX DENSITY. At a point, the vector whose magnitude is equal to the charge per unit area which would appear on one face of a thin metal plate introduced in the **electric field** at the point and so oriented that this charge is a maximum. The vector is normal to the plate from the negative to the positive face. The term electric displacement density or electric displacement is also in use for this term. In an isotropic medium of permittivity ϵ, the flux density is $\mathbf{D} = \epsilon\mathbf{E}$, where $\mathbf{E}$ is the electric field vector.

ELECTRIC GENERATOR. See **alternator;** and **direct-current generator.**

ELECTRIC IMAGE. See **electrostatics.**

ELECTRIC(AL) INSTRUMENT. See **instrument, electrical.**

ELECTRIC INSULATION. Any **dielectric** is an electric insulator, but experience has demonstrated the value of certain solids, such as glass, porcelain, rubber, mica, silk, paraffin, etc., for practical use. Oil and air also are often used where very high voltages are employed. With solid insulators, mechanical strength is often a consideration; as are also incombustibility, flexibility, non-hygroscopic character, high surface-resistance, the ability to withstand high temperatures, the possibility of being machined or molded, and moderate cost. Low dielectric constant would also be desirable in cases where distributed capacitance is to be minimized. The primary requirement of an insulator, however, concerns its insulating strength, that is, the maximum voltage per unit thickness which the material will sustain without electric breakdown or sparkover. (This is quite apart from its **resistivity.**) In reckoning this with alternating voltages, the maximum or peak voltage must be used, which is $\sqrt{2}$ or 1.41 times the effective voltage at which the service is rated.

(Thus the insulation on an 11,000-volt line must be able to sustain 15,600 volts.)

ELECTRIC JUNCTION EQUATION. See **Kirchhoff laws.**

ELECTRIC(AL) LENGTH. The physical length of a transmission line or its equivalent, corrected for any inhomogeneities that may effect the speed of propagation, and expressed in wavelengths, radians, or degrees.

ELECTRIC(AL) METHOD FOR LATENT HEAT OF FUSION. The substance is first cooled below its freezing point, and then electrically heated in a (vacuum) calorimeter. As the melting point is reached, heat has to be supplied without a rise in temperature taking place. Once the substance has been completely melted, heating will again take place as the liquid phase is warmed above the melting point. The energy supplied during the interval when the temperature was steady is the heat of fusion. For an accurate determination, knowledge of the specific heats of the solid and liquid forms near the melting point is essential.

ELECTRIC(AL) MODULATION. A facsimile term referring to the modulation of a carrier by the signal current in any form of electrical or electronic modulator.

ELECTRIC MOMENT. See **electrostatics; dipole moment.**

ELECTRIC MOTOR. See **motor, electric.**

ELECTRIC(AL) MUSICAL INSTRUMENTS. Any musical instrument which employs electrically or electronically operated sound generators or amplifiers. These include:

1. Vibration pickup attached to sounding board, amplifier and loudspeaker (e.g., electric guitar).
2. Electric pianos in which string vibrations are converted to electrical variations.
3. Electric organs either with or without direct use of electric oscillations.
4. Harmonic synthesizers.
5. Electric carillons with tuned coiled vibrators, magnetoelectric translators, amplifiers and reproducers.

ELECTRIC - NETWORK RECIPROCITY THEOREM. See **reciprocity theorem, electric-network.**

ELECTRIC NETWORKS, LAWS OF. See **Kirchhoff laws of networks,** etc.

ELECTRIC(AL) NOISE. See **noise, electrical.**

ELECTRIC OSCILLATIONS AND ELECTRIC WAVES. The most important early researches in this field were carried out by Heinrich Hertz, who, about 1888, discovered that when an electric discharge takes place in a circuit having suitable inductance and capacitance, the resulting oscillations of the electricity therein give rise to radiation, usually some meters in wavelength. The existence of the radiation was predicted by the **Maxwell equations** and was proved by its inducing oscillations in a similar circuit set up at a distance. He found that this Hertzian radiation can be reflected by metal surfaces and refracted by large blocks or prisms of dielectric material, just as light is reflected and refracted, and that it exhibits corresponding interference phenomena. The applications of Hertzian waves in radio are treated elsewhere. Electric waves may be propagated on long wires or through **waveguides** and **coaxial lines,** somewhat as sound waves travel through a long tube. By suitably terminating the line, the waves may be reflected and made to form interference nodes as do sound waves in an organ pipe. The wavelength may be thus determined by what is known as the **Lecher oscillator** method.

ELECTRIC(AL) POTENTIAL. See **potential, electric;** and **electromotive force.**

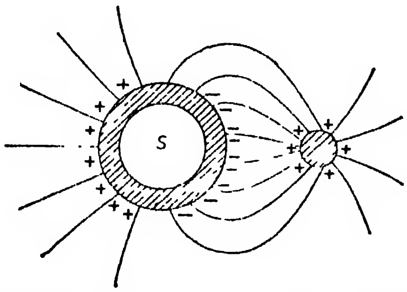
ELECTRIC(AL) RESISTIVITY. Compare discussion of **conductivity, electrical.**

ELECTRIC SCALAR POTENTIAL. See **wave potentials.**

ELECTRIC SHIELDING. See **screening.**

ELECTRIC SCREENING. The experiments of Faraday revealed that any region completely enclosed by metal or other good **conductor,** however thin, is entirely free from **electrostatic** fields due to anything going on outside the enclosure. Conductors are impervious to electric fields, because the free **electrons** in the conducting shell surrounding the enclosure instantly adjust themselves so as to offset the effect of any electrostatic force that would otherwise penetrate the interior. Even a cage of fairly coarse screen wire is

quite effective. Since **electromagnetic radiation** involves electric fields, we have here, an explanation of why metals are opaque to it.



Showing induction and external field Space S is completely shielded.

The screening effect of conductors is utilized in many kinds of electrical apparatus, as by enclosing electroscopes and the wires leading to them in metal cases or conduits, the placing of metal covers over radio tubes, etc. Whole buildings are sometimes covered with sheet iron to prevent induction sparks due to lightning from setting fire to inflammable contents, such as gasoline or explosives. (See **electrostatics; coaxial lines** and **wave guides.**)

ELECTRIC(AL) TRANSCRIPTION. A 16-inch, 33⅓ rpm recording mode, used primarily for broadcast purposes.

ELECTRIC TRANSDUCER. See **transducer, electric.**

ELECTRIC VECTOR. See **electric field vector.**

ELECTRIC VECTOR POTENTIAL. See **wave potentials.**

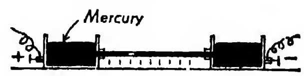
ELECTRIC WAVES. See **electric oscillations and electric waves.**

ELECTRICITY. The electrification of amber by rubbing with wool or fur was observed many centuries ago. Not until the work of Volta, late in the 18th century, was electricity recognized through any but electrostatic phenomena, and investigations on the properties and applications of electric currents were among the most brilliant features of 19th century physics. Even in the 1890's physicists were still asking, "What is electricity?" It had then long been known tha an appropriate application of energy will separate electricity into two components, designated as positive and negative; that bodies charged with these components attract each other; and that the energy of separation is yielded upon the reunion of the two components. It remained for J. J. Thomson to recognize the electron, and for the recent analysis of atomic structure to identify the proton. As a physical magnitude, methods have been devised for measuring quantities of electricity, not only in terms of the elementary electronic charge, but in larger units determined by electrostatic, electromagnetic, or electrochemical effects. Among the most important aspects of the subject are the magnetic properties of moving electricity, **electromagnetic waves**, and the incorporation of both components of electricity in the structure of all atoms and molecules of matter. (See **electrostatics;** and **Maxwell equations.**)

ELECTRIFICATION BY INDUCTION. See **induction, electrification by.**

ELECTROACOUSTIC TRANSDUCER. See **transducer, electroacoustic.**

ELECTROCAPILLARITY. The **surface tension** or interfacial tension between two conducting liquids in contact, such as mercury and a dilute acid, is sensibly altered when an **electric current** passes across the interface. As a result, when the contact is in a capillary tube, the pressure difference on the opposite sides of the meniscus is affected by a current traversing the capillary column, to an extent dependent upon the direction of the current across the boundary. This has been utilized in different forms of capillary electrometer.



Capillary electrometer

In the Dewar type, two small vessels of mercury are joined below the mercury level by a horizontal capillary tube, the mercury in which is interrupted by a short space filled with dilute acid. Upon applying a small potential difference to the two bodies of mercury, the equilibrium is disturbed and the drop of acid moves toward the low-potential end until the resultant capillary pressure is balanced by the hydrostatic pressure of the mercury. Since this effect is approximately proportional to the potential difference, the apparatus serves as an indicator for potentials of a few hundred millivolts.

ELECTROCAPILLARY CURVE. The curve obtained by plotting the **interfacial tension** of a mercury surface in contact with an aqueous solution of an **electrolyte** as a function of the applied potential.

ELECTROCHEMICAL EQUIVALENT. (1) The mass of any chemical substance liberated by one **coulomb** of electricity in electrolysis. For hydrogen it is 0.00001036 g. and this figure multiplied by the gram-equivalent weight of any substance will furnish its electrochemical equivalent. (2) Of electricity, the **faraday.**

ELECTRODE. In an electric circuit, part of which is composed of other than the usual conductor of copper, or other metal, the terminal connecting the conventional conductor and the conducting substances is an electrode. Examples of electrodes are to be found in the **electric battery**, where they dip in the **electrolyte;** the **electric furnace**, where the electrodes connect the external circuit with the heating arc; and the metallic elements in **thermionic tubes** and **gas-discharge** devices, and in **semiconductor** devices, where they perform one or more of the functions of emitting, collecting or controlling by an electric field the movements of electrons and ions.

ELECTRODE, ACCELERATING (OF AN ELECTRON-BEAM TUBE). An **electrode** the potential of which provides an **electric field** to increase the velocity of the beam-electrons.

ELECTRODE ADMITTANCE (OF THE jTH ELECTRODE OF AN n-ELECTRODE ELECTRON TUBE). The short-circuit driving-point admittance between the jth electrode and the reference point measured directly at the jth electrode. To be able to determine the intrinsic electronic merit of an electron tube the driving-point and transfer admittances must be defined as if measured directly at the electrodes inside the tube. The definitions of electrode admittance and electrode impedance are included for this reason.

ELECTRODE, ANTIMONY. An **electrode** of metallic antimony that has sufficient antimony oxide (Sb_2O_3) on its surface to function as an oxide electrode for the measurement of **pH.**

ELECTRODE, CALOMEL. A standard **electrode** of mercury, mercurous chloride (calomel), and potassium chloride. Its potential relative to the normal hydrogen electrode, if a molar potassium chloride solution is used, is 0.2800 volt at 25°C. (See also **electrode, Hildebrand.**)

ELECTRODE CAPACITANCE (OF AN n-TERMINAL ELECTRON TUBE. The capacitance determined from the short-circuit driving-point admittance at that electrode.

ELECTRODE CHARACTERISTIC. A relation, usually shown by a graph, between the electrode voltage and the current to an electrode, all other electrode voltages being maintained constant.

ELECTRODE CONCENTRATION CELL. See **cell, electrode concentration.**

ELECTRODE CONDUCTANCE. The real part of the **electrode admittance.**

ELECTRODE, CONTROL. An **electrode** on which a voltage is impressed to vary the current flowing between two or more other electrodes.

ELECTRODE CURRENT. In an electron tube, the current passing to or from an electrode through the interelectrode space. The terms cathode current, grid current, anode current, plate current, etc., are used to designate electrode currents for these specific electrodes. Unless otherwise stated, an electrode current is measured at the available terminal.

ELECTRODE CURRENT, AVERAGE. The value obtained by integrating the instantaneous electrode current over an averaging time, and dividing by the averaging time.

ELECTRODE - CURRENT AVERAGING TIME. The time-interval over which the current is averaged in defining the operating capabilities of the electrode.

ELECTRODE CURRENT, INVERSE. The current flowing through an electrode in the direction opposite to that for which the tube is designed.

ELECTRODE CURRENT, PEAK. The maximum instantaneous current that flows through an electrode.

ELECTRODE DARK CURRENT. In a phototube, the electrode current that flows when there is no radiant flux incident on the photocathode. Since **dark current** may change

considerably with temperature, temperature should be specified.

ELECTRODE EQUIVALENT DARK-CURRENT INPUT. The incident **luminous flux** that would be required to give an output current equal to the **electrode dark current.** Since dark current may change considerably with temperature, temperature should be specified.

ELECTRODE, DECELERATING. In an **electron-beam tube,** an electrode the potential of which provides an electric field to decrease the velocity of the **beam electrons.**

ELECTRODE, DEFLECTING. An electrode the potential of which provides an electric field to produce deflection of a beam of electrons or other charged particles.

ELECTRODE DISSIPATION. The power dissipated in the form of heat by an electrode as a result of electron and/or ion bombardment.

ELECTRODE, DROPPING. An **electrode** consisting of a steady flow of droplets of mercury into the **electrolyte** of a **cell.**

ELECTRODE, GAS. An electrode that contains a gas by **adsorption, absorption,** or other means which presents a gaseous surface to a solution in contact with the **electrode.**

ELECTRODE, GLASS. A thin-walled glass membrane, separating a solution of known **pH** from another solution whose pH is to be determined. A standard electrode dips into each of these two solutions. From the total **electromotive force** of the cell and the pH of the standard solution, the pH of the unknown may be calculated.

ELECTRODE, HILDEBRAND. Two electrodes bear the name of Hildebrand. (1) A modified calomel electrode (see **electrode, calomel**). (2) A platinum electrode in an apparatus containing hydrogen and used as a hydrogen electrode. (See **electrode, hydrogen.**)

ELECTRODE, HYDROGEN. (1) An **electrode** in which hydrogen gas at atmospheric pressure bubbles past a platinum-black electrode maintained in contact with an acid solution. (2) More generally, any electrode which can be used in the measurement of hydrogen ion concentration, such as the quinhydrone electrode, the glass electrode, and many others.

ELECTRODE IMPEDANCE. The reciprocal of the **electrode admittance.**

ELECTRODE, INTENSIFIER. A post-accelerating electrode. (See **cathode-ray tube, after-acceleration.**)

ELECTRODE, NORMAL CALOMEL. An **electrode** of mercury in contact with a normal solution of potassium chloride saturated with calomel.

ELECTRODE, NULL. An **electrode** having a **thermodynamic potential** of zero; i.e., an electrode in which there is actually no difference of potential between the metal and the ionic solution. It is believed, however, that no such electrodes have been prepared. Electrodes are known whereby, due to relative motion, it is possible to obtain an electrokinetic potential of zero, but it does not follow that their reversible potential is zero.

ELECTRODE OF THE SECOND ORDER. An **electrode** of metal in contact with one of its difficultly soluble salts in the presence of a solution of a salt which has the same anion as the less soluble salt. E.g.,

$$Hg/Hg_2Cl_2/KCl.$$

Electrodes of this type are not essentially different from an ordinary electrode in contact with a solution of one of its salts.

ELECTRODE, OXIDATION-REDUCTION. An inert (e.g., platinum) **electrode** in a mixture of oxidized and reduced ions, such as ferric-ferrous, stannic-stannous, quinone-hydroquinone.

ELECTRODE POTENTIAL. The **potential** of a metal in **equilibrium** with a solution of its ions. The establishment of electrode potential is regarded as the resultant of the rates of two processes, passage of ions from the electrode into solution, and discharge of ions from solution upon the electrode. Thus, the potential of an electrode is the component of cell potential (see **cell, electric**) associated with the reaction at one electrode.

ELECTRODE POTENTIAL, STANDARD. The potential of a given **electrode** relative to the hydrogen electrode when all the elements in both electrodes are in their **standard states.**

ELECTRODE, QUINHYDRONE. An electrode of **quinhydrone,** which accepts protons (hydrogen ions) to yield hydroquinone, and donates protons to yield *p*-benzoquinone, and has, therefore, a definite relation between its potential and the **pH** of the solution. Its values have been recorded at definite temperatures, and it is used as a standard electrode in **pH** measurement.

ELECTRODE RESISTANCE. The reciprocal of the **electrode conductance.** This is the effective parallel resistance and is not the real component of the electrode impedance.

ELECTRODE, REVERSIBLE. An electrode used in a reversible electrochemical reaction. There are three types of reversible electrodes used in reversible cells. The first type consists of a metal which is in contact with a solution containing its ions. The second type consists of a metal and one of its insoluble salts in contact with a solution containing a soluble salt with the same anion. This type of electrode is reversible with respect to the anions. The third type of electrode is a metal which is resistant to acids and bases, in contact with a solution which contains ions in two valence states. Oxidation or reduction is the reversible reaction which occurs at this type of electrode.

ELECTRODE, SELF. In emission spectroscopy, an **electrode** composed of the material being analyzed.

ELECTRODE, SIGNAL. In a **camera tube,** an electrode from which the signal output is obtained.

ELECTRODE(S), SLIDING. An arrangement whereby electrodes enclosed within a glass vessel may have several different configurations. For example, a movable system may be mounted in such a way that it can slide along a wire or glass-rod framework into different positions.

ELECTRODE, SUPPORTING. In emission spectroscopy, an **electrode,** other than a self-electrode, on or in which the sample is supported.

ELECTRODE VOLTAGE. The voltage between an electrode and the **cathode** or a specified point of a filamentary cathode. The terms grid voltage, anode voltage, plate voltages, etc., are used to designate the voltage between these specific electrodes and the cathode. Unless otherwise stated, electrode voltages are understood to be measured at the available terminals.

ELECTRODELESS DISCHARGE. A discharge in a gas tube produced not by potentials between its electrodes, but by the placement of the tube in intense high-frequency electromagnetic fields. Thus the gas is not subject to contamination or other change by the presence of electrodes. This device is frequently used in the study of the spectra of gases and vapors. (See also **gas-discharge tube.**)

ELECTRODIALYSIS. The removal of **electrolytes** from a colloidal solution by a combination of **electrolysis** and **dialysis.** Usually the colloidal solution is placed in a vessel with two dialyzing membranes with pure water in compartments on the other side of the membranes. Two electrodes are inserted in the pure water compartments and an applied emf causes the ions to migrate from the colloidal solution.

ELECTRODYNAMIC VOLTMETER. See **electrodynamometer.**

ELECTRODYNAMIC WATTMETER. See **wattmeter, electrodynamic.**

ELECTRODYNAMOMETER. A meter having both a fixed coil and a movable coil, whose deflection depends on the interaction of the magnetic fields produced by the currents of the two coils. The coils may be either in series or in parallel to yield a **square-law** meter for measurement of voltage or current. Such a meter can be calibrated on d-c and used for a-c measurements. By connecting one coil across a load, and the other in series with the load, the electrodynamometer becomes a **wattmeter.**

ELECTROENDOSMOSIS. **Electrophoresis** in which the solid is stationary and the water phase is displaced and migrates toward the electrode.

ELECTROFORMING. The **electrolytic deposition** of metal upon a conducting mold, to make a desired metal object, such as precision tubing or medals. The mold is often of graphite-coated wax, so that it can be removed by melting. (See **electroplating.**)

ELECTROKINETIC EFFECTS. Movements of particles under the influence of an applied electric field.

ELECTROKINETIC (ZETA) POTENTIAL. The difference in potential between the immovable liquid layer attached to the surface of a solid phase and the movable part of the diffuse layer in the body of the liquid.

ELECTROLYSIS. The process of decomposing a chemical compound by passing a current of electricity through it either in its natural form, or in solution, or in molten form.

ELECTROLYSIS, FARADAY LAWS OF. See **Faraday laws of electrolysis.**

ELECTROLYTE. (1) Any substance whose solutions have the property of conducting the electric current. All soluble **acids, bases,** and **salts** are electrolytes. (2) A solution which conducts the electric current.

ELECTROLYTE(S), ANOMALY OF STRONG. The **Arrhenius theory of ionization** is quite satisfactory for predicting the properties of dilute solutions of strong electrolytes, but it fails for their concentrated solutions. The **Debye-Hückel theory** resolves this difficulty by recognizing that strong electrolytes are nearly completely ionized in water solution, and that there are practically no unionized molecules present. Instead, it is considered that the free ions become bound by acquiring an ionic atmosphere which reduces their **mobility.**

ELECTROLYTE, COLLOIDAL. A compound having a long **hydrocarbon** chain terminating in a group that can ionize. Colloidal electrolytes resemble nonelectrolytes in some of their properties and **electrolytes** in others. Thus, the alkaline salts of the fatty acids, for example, have the osmotic properties of a nonelectrolyte, but they show a marked electrical conductance and other properties of weak electrolytes.

ELECTROLYTE, CONDUCTANCE OF. See **conductance of electrolyte.**

ELECTROLYTE, MEAN ACTIVITY OF. See **mean activity of an electrolyte.**

ELECTROLYTE, STRONG. One of a group of substances, comprising strong acids, strong bases and many salts, characterized by having an equivalent conductance (see **conductance, equivalent**) which drops rapidly as the concentration is increased.

ELECTROLYTE, WEAK. One of a group of substances, mainly organic acids and bases, characterized by equivalent conductances (see **conductance, equivalent**) that drop slowly as the concentration is increased.

ELECTROLYTES, THEORY OF. The fundamental idea underlying the modern view of electrolyte behavior, as formulated by Debye and Hückel, is that as a consequence of electrical attractions between positive and negative ions there are, on the average, more ions of unlike than of like sign in the neighborhood of any ion. Every ion may, therefore, be regarded as being surrounded by an ionic atmosphere of opposite charge. As long as the system is "stationary," that is to say, it is not exposed to an applied electric field or to a shearing force which tends to cause the liquid to flow, the ionic atmosphere has central symmetry. When a current is passed through the solution, however, so that the ions of a particular sign move, say, to the right, then each ion during its motion will constantly have to build up its ionic atmosphere to the right, whereas the charge density to the left will die out. If this formation and destruction of the ionic atmosphere occurred instantaneously, there would be no net force of attraction on the moving ion, but in effect there is a definite time of relaxation during which the atmosphere to the right is building up to its equilibrium value and that to the left is decaying. Since the charge of the ionic atmosphere is opposite to that of the moving ion, there will be an excess of ions of opposite sign to the left and these will retard the motion. The influence on the velocity of the ion is known as the relaxation effect, or sometimes as the asymmetry effect, because it arises from the lack of symmetry in the electrical atmosphere of a moving ion. In addition to the foregoing, another factor will help to oppose the motion of the ions: this is the tendency of the applied emf to move the ionic atmosphere, with its associated molecules of solvent, in a direction opposite to that in which the ion, accompanied by solvent molecules is itself moving. The additional retardation arising in this manner is called the electrophoretic effect, since it is analogous to that opposing the movement of a colloidal particle in an electric field. Finally, the mi-

gration of the ion is opposed by the normal frictional resistance of the medium; this is determined by Stokes's law, and depends on the speed of the ion, its radius and the viscosity of the medium. When the ion moves with steady velocity the three retarding forces are just balanced by the electrical force due to the applied emf. At infinite dilution the asymmetry and electrophoretic effects are virtually zero, and the speeds of the ions, and hence the equivalent conductance, are determined only by the frictional force of the medium. The difference between the equivalent conductance at infinite dilution and at an appreciable concentration is, therefore, a direct consequence of the two electrical forces, assuming the viscosity of the solution to be little different from that at infinite dilution, i.e., that of the solvent (Glasstone, *Textbook of Physical Chemistry*, 2d ed., Van Nostrand (1946), q.v. for further treatment.)

ELECTROLYTIC CAPACITOR. See **capacitor, electrolytic.**

ELECTROLYTIC CONDUCTOR. Electrolytes, conductors in which the passage of electricity is accompanied by the transfer of matter, as distinguished from electronic conductors, such as metals.

ELECTROLYTIC DISSOCIATION, ARRHENIUS THEORY OF. See **Arrhenius theory of electrolytic dissociation.**

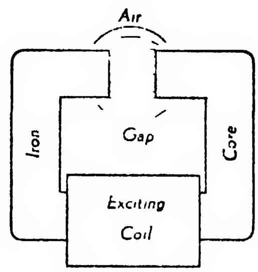
ELECTROLYTIC POLARIZATION. See **polarization, electrolytic.**

ELECTROLYTIC POLISHING. The process of producing a smooth lustrous surface on a metal by making it the anode in an electrolytic solution and preferentially dissolving the protuberances.

ELECTROLYTIC RECTIFIER. An electrolytic system which converts alternating current to direct current. It consists essentially of a combination of two **electrodes** and an **electrolyte** which produces a polarizing film on one of the electrodes that practically bars the flow of current into it from the solution, while freely permitting flow in the opposite direction. Groups of these cells may be arranged to utilize both halves of the alternating-current cycle.

ELECTROLYTIC SOLUTION PRESSURE. The tendency of a metal or other substance to dissolve in solution with the formation of ions: a now obsolete concept used by Nernst to explain **electrode potentials.** The establishment of electrode potential is now regarded as the resultant of the rates of the two processes, passage of ions from the electrode into solution, and discharge of ions from solution upon the electrode.

ELECTROMAGNET. A **magnet** whose field is produced by an **electric current,** and which is largely demagnetized upon cessation of the current, is an electromagnet. In order to obtain the strongest field possible, highly permeable soft iron or steel is employed for the



ELECTROMAGNET
Sketch of electromagnet having two poles; one of a large variety of designs

core of electromagnets. In an electromagnet the current flows through a solenoid, which is a conductor wound in the form of a **helix,** and which produces a strong magnetic field coaxial with the helix. The core is placed inside the helix in order to give a magnetic path of the least reluctance. Electromagnets are found in a number of different forms, such as the plain solenoid with cylindrical core, or the horseshoe electromagnet, much used in electric bells, telegraph instruments, and telephones. Very powerful electromagnets are often used to move masses of iron, such as scrap iron, and have the advantage that the loading or unloading of the crane to which the magnet is attached is simply a matter of applying or disconnecting the electric current. For practical approximate calculations, we ignore the fringing of the field at the air gap, and compute the flux by the Bosanquet law (analogous to the **Ohm law**).

$$\text{Flux} = \frac{\text{magnetomotive force}}{\text{reluctance}}\,; \quad \phi = \mathfrak{F}/\mathfrak{R}.$$

Ignoring frequency, the reluctance of an air gap of length l and cross-sectional area A is

$$\mathcal{R}_g = \frac{l}{\mu_t A}$$

while that of the core of length L is

$$\mathcal{R}_c = \frac{L}{\mu_s \mu_r A}$$

making the total: $\mathcal{R} = \mathcal{R}_g + \mathcal{R}_c$. The magnetomotive force, in rationalized units, is $\mathcal{F} = NI$. Using mksa units, l is in meters, A in square meters, I in amperes, $\mathcal{F}$ in ampere-turns, and the flux (ϕ) in webers.

ELECTROMAGNETIC CONSTANT. The speed of propagation of electromagnetic waves such as **light,** in a vacuum, commonly denoted by c, appears so frequently in physical formulae that it has become one of the most important of all physical constants. This is especially true since the advent of multitudes of formulae of **relativity** involving this factor. The precise determination of its value has justly, therefore, engaged the attention of the ablest experimenters. A long history of direct measurements culminated in the method which was perfected and refined by Michelson and others Michelson's final value (1930) was 299,772 kilometers per sec. The most probable value, as of 1941, is given by Birge as 299,776 kilometers per sec Postwar experiments using microwaves and other techniques indicate that 299,793 kilometers per sec is a better value.

ELECTROMAGNETIC DEFLECTION COIL. The coil used to produce electromagnetic deflection. In **cathode-ray tubes** the assembly containing one or more of these coils is called the **yoke.**

ELECTROMAGNETIC FIELD. It is commonly stated that a wire carrying an electric current is surrounded by a magnetic field whose lines of force are circles with the wire as their axis. This statement implies that the magnetic field is directly traceable to the moving electricity in the wire. There is, however, another aspect of the matter. Each electric particle projects into space a field of electric force, and as the particles move along the wire the lines of force move with them. According to the theory of Maxwell, it is the motion of these lines of electric force that sets up the magnetic field transverse to them. More generally, a variable electric field is always accompanied by a magnetic field; and conversely, a variable magnetic field. is accompanied by an electric field. The joint interplay of electric and magnetic forces here described is what is called an electromagnetic field, and is considered as having its own objective existence in space apart from any electric charges or magnets with which it may be associated. An essential feature of the theory is that this process, whatever it is, represents a flow of energy at right angles to both electric and magnetic components when the fields vary with time. The flux density of this energy (corresponding to the intensity of radiation) is represented by what is known as the **Poynting vector.** Electromagnetic radiation is, on this theory, the propagation of electric and magnetic stresses through space with the speed of light, somewhat as the much slower waves of elastic stress are propagated through steel. The conditions in an electromagnetic field are expressed mathematically by the well-known **Maxwell equations.** When an electric charge is set into motion, it builds about itself an electromagnetic field, and this implies a distribution of energy throughout space. The density of this energy at any point of the field is proportional to the product of the electric and magnetic vector components and the sine of the angle between them (vector product). The total field energy can be obtained by suitable integration, and is greater than that of the purely electric field of a stationary charge The Maxwell theory treats this excess as kinetic energy, thus endowing the moving charge with an "electromagnetic mass" and an "electromagnetic momentum" inherent in its electrical character.

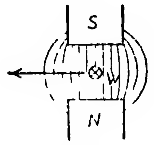
ELECTROMAGNETIC INDUCTION. Probably the most noteworthy of the many scientific contributions of the renowned Michael Faraday was his discovery in 1831 of electromagnetic (or more logically, magnetoelectric) induction. As exhibited in the usual experimental arrangements, this phenomenon is the setting up, in a circuit, of an **electromotive force** by reason of the variation of the magnetic flux linked with the circuit; the magnitude of that electromotive force being, as Faraday found, proportional to the rate at which the flux through the circuit, or the "linkage," varies. If the flux linkage with

the circuit, in weber-turns is expressed by $N\phi$ (the actual flux, ϕ, times the number of turns, N), the electromotive force generated by its variation, in volts, is:

$$E = N\frac{d\phi}{dt}.$$

The electromotive force is positive (counter-clockwise) when $d\phi/dt$ is positive, that is, when the flux is increasing, negative when it is decreasing; as viewed by one looking in the direction of the magnetic induction. More generally, the electromotive force always has such a direction that any current set up by it opposes the change in flux, in accordance with the **Lenz law.**

Another aspect of the matter is that if a conductor moves through a magnetic field, or if a magnetic field sweeps over a conductor, in such a way that the conductor cuts across the lines of force, the electricity in the conductor experiences forces at right angles to the field and to the (relative) motion More



Wire W moving to the left across an upward magnetic field has induced in it an emf away from the observer

general still is the Maxwell concept that when magnetic lines of force move sidewise, then movement results in an electric field at right angles to the magnetic lines and to their motion (See **electromagnetic field.**)

ELECTROMAGNETIC LOUDSPEAKER. See **loudspeaker, electromagnetic.**

ELECTROMAGNETIC MASS. See **electromagnetic field.**

ELECTROMAGNETIC MICROPHONE. See **microphone, variable-reluctance.**

ELECTROMAGNETIC RADIATION. See **radiation; Maxwell laws; γ-rays, x-rays; ultraviolet radiation; light; infrared radiation; microwaves; radio waves; electromagnetic field.**

ELECTROMAGNETIC REPULSION. The force of repulsion between two circuits when a current is supplied to one, and thence induces a current in the other.

ELECTROMAGNETIC THEORY OF DIELECTRIC REFLECTION AND REFRACTION. Light being an electromagnetic wave, the application of proper boundary conditions to the **Maxwell equations** give the laws of **reflection** and **refraction.** The principal boundary condition applicable is that at a boundary, the components parallel to the surface of both the **electric** and the **magnetic fields** must have no discontinuity at that boundary.

ELECTROMAGNETIC THEORY OF LIGHT. Light consists of vibrating electric and magnetic fields perpendicular to each other and to the direction of travel of the wave (See Robertson, *Introduction to Optics,* 4th Edition)

ELECTROMAGNETIC UNITS. See **EMU system of units.**

ELECTROMAGNETIC WAVE. A wave characterized by variations of electric and magnetic fields Electromagnetic waves are known as radio waves, heat rays, light rays, etc , depending on the frequency.

ELECTROMAGNETIC WAVE, SINUSOIDAL. In a homogeneous medium an **electromagnetic wave** whose **electric field strength** is proportional to the sine (or cosine) of an angle that is a linear function of time, of distance, or of both

ELECTROMAGNETISM. The pioneer discovery of the magnetic effect of the **electric current** was made by Oersted at Copenhagen in 1820. In experimenting with battery currents, he happened to bring a compass needle near a wire in which there was an electric current, and noted that the needle was deflected Such a wire is surrounded by a magnetic field so that, to one looking along the wire in the direction from the positive to the negative battery-terminal (the so-called "direction of the current"), the direction of the field, as indicated by the north pole of the compass needle, is clockwise (Ampère rule).

If the wire carrying the current is placed in a magnetic field perpendicular to its direction, this field reacts with that due to the current in such a way as to give the wire a lateral thrust, perpendicular to both the wire and the field in which it is placed For a wire of length l carrying current I and placed across flux of density B, this lateral force is given

by the equation $f = BlI$; which follows from the definition of the **ampere.** An electric motor may be driven by forces thus produced.

If the wire is bent into a circular loop of radius r, still carrying current I, there is produced at its center, perpendicular to the plane of the loop, a magnetic field of intensity $H = I/2r$. This, and the statement in the preceding paragraph, may be shown to be interdependent. If more loops are added, forming a coil of n equal turns close together, the resulting field is n times as great. By winding the n turns along a cylinder, forming a "helix" of radius r and axial length a, one obtains something greatly resembling a bar magnet, the ends of the helix corresponding to the poles. The field intensity at the center of the axis of this helix is

$$H_0 = \frac{nI}{\sqrt{4r^2 + a^2}}.$$

The above expressions are all appropriate in the rationalized **mksa system;** they may be converted to forms appropriate to other systems with the help of Table 3 of the Introduction. If we now insert an iron core, we have an electromagnet, and the helix supplies the magnetomotive force nI for a magnetic circuit composed partly of iron and partly of air. More general calculations of electromagnetic effects are based upon the **Ampere law,** the **Biot-Savart law,** and the **Maxwell equations.**

ELECTROMAGNETISM, ENERGY THEOREMS OF. See **Poynting theorem.**

ELECTROMECHANICAL TRANSDUCER. See **transducer, electromechanical.**

ELECTROMETER. An instrument for measuring electric charge, usually by mechanical forces exerted on a charged electrode in an electric field. It consists, therefore, of a sensitive voltmeter operating on the principles of electrostatic attraction and repulsion. Thus, if the movement of the gold-leaf in an **electroscope** is observed through a microscope whose ocular is provided with a calibrated scale, the instrument becomes an electrometer, capable of measuring potential differences in millivolts. (Some forms of electrostatic **voltmeter** operate on the same principle.) If the **capacitance** of the charged system is known, the rate of movement of the electrometer index may be used to measure the current from the discharging body; ionization currents are often thus measured.

The quadrant electrometer has a thin, oblong, metal plate suspended horizontally in the interior of a flat, circular metal box cut into four quadrants. One pair of opposite quadrants and the suspended strip are connected to the source of potential, the other

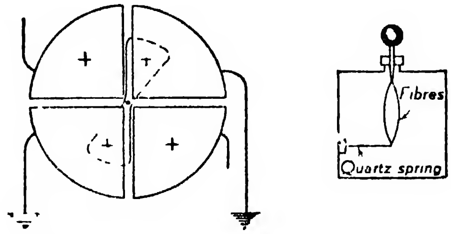


Fig 1 Quadrants and strip of quadrant electrometer
Fig 2. Quartz fiber electrometer

pair of quadrants is grounded. This causes the strip to turn toward the grounded pair against the torsion of the suspending wire. Several electrometers have been designed, depending upon the lateral deflection of a lightly stretched, silvered or platinized quartz fiber in an electric field; they are called string electrometers. The Wulf electrometer employs two such fibers side by side; on being charged, they bulge apart The displacement of the fibers is observed in a micrometer microscope. Some of the special electrometers used for work with **cosmic rays** are of this type.

In modern work, vacuum tube electrometers, which are specially designed **amplifiers** with high input impedance, have replaced quadrant and string electrometers to a large extent.

ELECTROMETER, CONNECTION OF. A quadrant **electrometer** may be used in either of two ways: (1) in the **heterostatic** connection, with a high voltage needle and the observed voltage across the quadrant-pairs, or (2) in the **idiostatic** connection, with the needle connected to one quadrant-pair. The latter connection is less sensitive, but may be used for a-c measurements since it has a **square-law** response.

ELECTROMETER, HOFFMAN. A modification of a quadrant **electrometer,** using binants instead of quadrants. The needle is mounted asymmetrically in an almost unstable position, yielding high **sensitivity.**

ELECTROMETER, IONIZATION. An **electrometer** which records the ionization produced by radioactivity in the neighborhood of an **ionization chamber.**

ELECTROMETER, KELVIN. An attracted-disc **voltmeter** (for very high voltages) with a guard-ring around the movable plate to avoid field-fringing effects.

ELECTROMETER, LINDEMANN. A very small, portable, quadrant **electrometer,** designed to be insensitive to changes in level. The needle deflection is observed through a microscope.

ELECTROMETER, QUADRANT. Discussed under **electrometer.**

ELECTROMETER, STRING. An **electrometer** in which a very fine conducting fiber is held under slight tension between two oppositely-charged plates, and is viewed through a microscope provided with an etched scale in its eyepiece. The charging of the fiber causes it to shift toward the plate of opposite sign.

ELECTROMETER TUBE. A specially-designed, **thermionic vacuum tube** for measuring exceedingly small currents.

ELECTROMETER, VACUUM TUBE. An electrometer in which the ionization current in an **ionization chamber** passes through a high resistance (of order 10^{10} ohms or higher). The voltage drop across the resistance is then amplified by a special vacuum tube.

ELECTROMETER, VIBRATING REED. An **electrometer** using a vibrating condenser to measure a small charge. This term is often applied to denote the combination of an **ionization chamber** and a vibrating reed electrometer.

ELECTROMETER, WULF. Discussed under **electrometer.**

ELECTROMOTIVE FORCE (EMF). The electric **potential** difference between the terminals of any device which is used or may be used as a source of electrical energy, i.e., to supply an electric current. More strictly, the limiting value of that potential difference which is found as the current flowing from the source approaches zero. To avoid ambiguity, the strict sense of the term is often indicated by the use of the qualifying term "open circuit" or "no load."

The open circuit electromotive force of a **cell** is identical with its reversible potential difference; that of a rotating electrical machine is the potential difference existing across its terminals when the machine is neither receiving nor delivering electric power, i.e., is at the transition point between being a generator and being a motor. When a potential source of electrical energy, such as a **capacitor,** an **inductor,** or a **rotating machine,** is receiving energy from the external circuit, it is said to develop a counter-electromotive force. (See also **Kirchhoff laws.**)

ELECTROMOTIVE FORCE, AVERAGE. For an alternating voltage (with no d-c component) the average value is zero. The term is often misused to mean the average absolute emf:

$$\frac{1}{T}\int_0^T |\mathcal{E}|\,dt.$$

For a sine wave, this is $2/\pi$ times the peak value.

ELECTROMOTIVE FORCE, BACK. An **electromotive force** which acts in a direction opposite to the applied electromotive force. It is a counter-electromotive force.

ELECTROMOTIVE FORCE, CELL. See **cell emf.**

ELECTROMOTIVE FORCE, COUNTER-. The **electromotive force** generated by a running **motor,** by virtue of its **generator** behavior, or by an inductive circuit element through which the current is increasing with time. The total emf in the circuit is the impressed emf minus the counter emf; the current is given by the ratio of this total emf to the resistance in the circuit.

ELECTROMOTIVE FORCE, EFFECTIVE OR ROOT-MEAN-SQUARE. The rms value of a periodic variable is

$$\left[\frac{1}{T}\int_0^T x^2 dt\right]^{1/2}$$

which for a sine wave is $1/\sqrt{2}$ times the peak value.

ELECTROMOTIVE FORCE, IMPRESSED. The open-circuit (no load) **electromotive force** of a source connected into a **network.**

ELECTROMOTIVE FORCE, MOTIONAL. The **electromotive force** induced in a circuit by virtue of motion of the conductor across a magnetic field:

$$\mathcal{E} = \int \mathbf{V} \times \mathbf{B} \cdot d\mathbf{l},$$

where **V** is the velocity of the conductor, **B** is the magnetic flux density, and the integral extends over the length of the conductor, **dl** being an element of length.

ELECTROMOTIVE FORCE SERIES. An arrangement of **elements** in order of decreasing potentials of their **electrodes** in equilibrium with solutions of their ions. Since the **electrode potential** of a metal in equilibrium with a solution of its ions cannot be measured directly, the values in the electromotive force series are, in each case, the difference between the electrode potential of the given metal in equilibrium with a solution of its ions, and that of hydrogen in equilibrium with a solution of its ions. In experimental procedure, the hydrogen electrode is used as the standard with which the electrode potentials of other substances are compared.

ELECTRON. An elementary particle of rest mass $m_e = 9.107 \times 10^{-28}$ g and charge of 4.802×10^{-10} statcoulomb, and a **spin** of one-half unit, i.e., of $\hbar/2 = h/4\pi$. Its charge may be positive or negative, although the term electron is commonly used for the negative particle, which is also called the negatron. The positive electron is called the **positron.**

ELECTRON AFFINITY. (1) Degree of **electronegativity,** or the extent to which an atom holds valence electrons in its immediate neighborhood, compared to other atoms of the molecule. (2) The work required to remove an electron from a negative ion, and hence to restore the neutrality of an atom or molecule is called the electron affinity of the atom or molecule.

ELECTRON ANOMALOUS MAGNETIC MOMENT. See **anomalous magnetic moment (electron).**

ELECTRON AVALANCHE. See **avalanche effect.**

ELECTRON BEAM. A stream of electrons moving with about the same velocity and in the same direction, so as to form a beam.

ELECTRON BEAM, MAGNETICALLY-CONFINED. An electron beam which is confined to a given path by the use of appropriate magnetic fields.

ELECTRON BEAM, SPACE CHARGE IN. See **space charge.**

ELECTRON-BEAM TUBE. See **tube, electron-beam.**

ELECTRON, BONDING. An electron in a molecule which serves to hold two adjacent **nuclei** together.

ELECTRON CAPTURE. A radioactive transformation of a nuclide in which a bound electron merges with its nucleus, decreasing the **atomic number** by 1, and leaving the **mass number** unchanged in the new nuclide formed. The fundamental process involved is represented by the equation $p + e^- \rightarrow n + \nu$; in words, a proton is transformed to a neutron within the nucleus, a bound electron is taken up, and a neutrino emerges with energy equal to the difference between the **disintegration energy** and the original **binding energy** of the electron. The bound electron comes most commonly from the atomic or molecular orbital of the atom or molecule which contains the transforming nucleus (a process called orbital-electron capture). In a metal, it may be a conductivity electron. Capture of unbound electrons by nuclei has not been observed. K-electron capture, L-electron capture, etc., are terms used where the atomic shell occupied by the electron captured is known.

As a result of the removal of an inner-shell electron, there is emission of **x-rays** and **Auger electrons** characteristic of the product element. γ-rays are also emitted in certain cases where the product nuclei are left in excited states. The value of the disintegration energy determines whether the electrons are captured chiefly from the K-shell or from other shells, or whether positron emission may occur as a competing process. The last process is more probable than electron capture for light elements, while the converse is true for heavy elements.

ELECTRON COLLECTION. A technique in **ionization chamber** measurements which takes advantage of the high mobility of free electrons as compared with ions.

ELECTRON CONCENTRATION. The ratio of the number of **valence electrons** to the number of atoms in a molecule. This quantity is useful in studying the intermetallic **compounds,** where it is correlated with the crystal structure.

ELECTRON, CONDUCTION. An electron which plays an important part in electrical or thermal conduction by solids, i.e., by metals or semiconductors, e.g., the electrons in the **conduction band,** which are free to move under the influence of an electric field.

ELECTRON-COUPLED OSCILLATOR. See **oscillator, electron-coupled.**

ELECTRON COUPLING. The combination of the **orbital** and **spin angular momentum** vectors for a group of electrons. Various types of electron coupling have been postulated for different groups of electrons, especially those of the elements; and have been applied in calculating resultant **quantum** numbers, which are useful in interpreting the **multiplet terms** in spectra.

ELECTRON DEVICE. A device in which conduction by electrons takes place through a vacuum, gas, or **semiconductor.**

ELECTRON DIFFRACTION. Beams of high-speed electrons exhibit **diffraction** phenomena analogous to those obtained with light, thus showing the wave-like character of electron beams. Such patterns are useful in the interpretation of the structure of gases or solids.

ELECTRON DISTRIBUTION. An arrangement of electrons, especially the arrangement of electrons in **orbits** or **shells** around the **nucleus** of an atom or an ion.

ELECTRON DONOR. (1) When a valence **bond** between two atoms is that type of covalent linkage in which both the electrons of the duplet are supplied by one atom, then that atom, or portion of the molecule of which it forms a part, is called the electron donor, and the other atom in the linkage is called the electron acceptor. (2) See **impurity, donor.**

ELECTRON DUPLET. A pair of electrons which is shared by two atoms, and is equivalent to a single, nonpolar chemical **bond.**

ELECTRON EMISSION. The liberation of electrons from an electrode into the surrounding space. Quantitatively, it is the rate at which electrons are emitted from an electrode.

ELECTRON(S), EQUIVALENT. See **equivalent electrons.**

ELECTRON, EXTRANUCLEAR. In an atom, any one of the electrons that surround the positive **nucleus.**

ELECTRON, FREE. (1) An electron which is not restrained to remain in the immediate neighborhood of a **nucleus** or an **atom.** (2) The term free electron is also applied to any electron in the outer electronic shell of an atom, when that electron is not shared by another atom, and especially when that electron is free to be so shared (to form a covalent bond).

ELECTRON GAS. A system of mobile electrons, generally as it exists within a **metal.**

ELECTRON GROUP OR SHELL. A number of electrons occupying similar relative positions, as those extranuclear electrons which possess the same principal quantum number. (See **quantum number, principal.**)

ELECTRON GUN. An electrode structure which produces and may control, focus, and deflect an **electron beam.**

ELECTRON GUN, AXIALLY SYMMETRICAL. An **electron gun** having an electron beam controlled with symmetry about the axis of the beam.

ELECTRON GUN, RECTILINEAR FLOW. An **electron gun** having an electron beam controlled with rectilinear symmetry.

ELECTRON IMAGE TUBE. A **cathode-ray tube** used to increase the brightness or size of an image or to produce a visible image from invisible radiation such as infrared. A large, light-sensitive, cold cathode serves as the focal plane for the optical image. The resulting emission from the cathode is accelerated through an appropriate lens system before striking a fluorescent screen, where it produces an enlarged and brightened reproduction of the original image. This device has been employed in electron microscopes and telescopes, infrared microscopes and telescopes, and fluoroscope intensifiers.

ELECTRON LENS. An electron moving in an inhomogeneous electric or magnetic field in

general follows a curved trajectory. It may be shown that the trajectories in certain fields are such that all electrons which pass through a given point subsequently pass through, or close to, a second point, whose location is fixed by the field strengths, and by the position of the first point. The paths of electrons in such a system therefore bear a striking resemblance to the light rays which pass through a lens, and the set of electrodes or of conductors which establish the necessary fields is known as an electron lens. The focal length of the lens is defined in the same way as is the focal length of an optical lens; it may be varied by changing the field strengths. As an example of an electron lens, a slit or hole in a conducting sheet acts to converge or diverge electrons if the electric fields on the two sides of the sheet differ in strength.

ELECTRON MICROSCOPE. A microscope in which streams of electrons function in essentially the same way as rays of light do in an ordinary optical microscope. When it is recalled that moving electrons exhibit properties characteristic of trains of waves (see **wave mechanics**), the analogy becomes still more striking; while the very short wavelength associated with electron waves serves to give the electron microscope extraordinary **resolving power,** thus making available magnifying powers far beyond the reach of any optical instrument.

ELECTRON MIRROR. A **dynode.**

ELECTRON MULTIPLICATION. On bombarding certain surfaces by electrons it may happen that each impinging electron expels several electrons from the struck surface. If these electrons are caught in an electric field and driven against another similar surface, each of them may again give rise to several electrons After several such stages of multiplication, an appreciable **pulse** may be obtained in this manner, starting with a single electron as β-radiation, or produced photoelectrically by γ-radiation. Quantitatively, the electron multiplication of a device such as a photo-multiplier is the ratio of the number of electrons reaching the anode to the number emitted at the cathode.

ELECTRON MULTIPLIER. A device for amplifying by a process of **electron multiplication.**

ELECTRON MULTIPLIER, ELECTROSTATIC. An electron multiplier (see **multiplier, electron**) which accelerates and focuses the electrons by the use of electrostatic fields.

ELECTRON MULTIPLIER TUBE. A tube employing **electron multiplication,** usually a photoelectric device.

ELECTRON, NUCLEAR. An electron which is emitted from the **nucleus** of an atom. Its formation within the nucleus is believed to be due to the transformation of a **proton** into a **neutron.** It is not now believed that electrons exist as such inside the nucleus.

ELECTRON OCTET. An **electron group** or **electron shell** containing eight electrons.

ELECTRON OPTICS. The control of the movement of free electrons by means of electric fields, and their utilization in research investigation of electronic diffraction phenomena, in direct analogy to the effect of lenses on light. Electron beams are used to determine the microstructure of crystals and many other materials (See **electron microscope** and **electron diffraction.**)

ELECTRON, ORBITAL. An electron remaining with a high degree of probability in the immediate neighborhood of a **nucleus,** where it occupies a quantized **orbital.**

ELECTRON PAIR. A general feature of the architecture of many molecular structures, in which neighboring atoms or nuclei are bonded by sharing a pair of valence electrons, forming a nonpolar bond. (See **bond, nonpolar.**)

ELECTRON, PAIRED. One of two electrons which are shared by two atoms to form a valence **bond.**

ELECTRON, PHOTO. An electron ejected from a substance by the action of light or other **radiation.**

ELECTRON POLARIZATION. The part of the total induced **polarization** of a molecule that is due to the distortion or deformation of the electron shells or orbits under the influence of external electric fields.

ELECTRON-POSITRON PAIR. An electron and positron produced at the same time in the process of **pair production.**

ELECTRON RADIUS, CLASSICAL. A quantity given by the expression: $r = e^2/m_ec^2$

where e is the electronic charge, m_e is the electronic rest mass, c is the velocity of light, and r is the electron radius. This expression, which has a value of 2.82×10^{-13} cm, is obtained by equating the rest-mass energy m_ec^2 of the electron, to its electrostatic self-energy, e^2/r.

ELECTRON, RELATIVISTIC CORRECTIONS FOR. At electron-volt energy levels above about 10,000 electron-volts, the mass of the electron is increased sufficiently due to the relativity theory to require modification of the simple expression ($\frac{1}{2}mv^2$) for kinetic energy. For any velocity the kinetic energy of an electron may be expressed as:

$$\frac{mc^2}{(1 - v^2/c^2)^{1/2}} - mc^2$$

where m is the **electron mass** of 9.11×10^{-31} Kg, v is the velocity of the electron and c that of light.

ELECTRON, SECONDARY. An electron deriving its motion from a transfer of momentum from primary radiation, which may be either particulate or electromagnetic.

ELECTRON SHELL. The arrangement of extranuclear electrons in different groups of **orbitals** which are characterized by different principal quantum numbers. (See **quantum number, principal.**) In the old Bohr model of the atom, all electrons in a given shell moved in orbits of approximately the same distance from the nucleus. Different shells are then characterized by different dimensions of the electronic orbits.

ELECTRON SPIN. The intrinsic angular momentum of an electron, independent of any orbital motion. Spin ($= \hbar/2$) contributes to the total angular momentum of the electron and is quantized. It gives rise to **multiplicity** in line spectra, which may be characterized by introduction of the **spin quantum number.**

ELECTRON TELESCOPE. A device by means of which an infrared image of a distant object, focused upon a photosensitive cathode, gives rise to an enlarged electron image on a fluorescent screen, as in an **electron image tube.**

ELECTRON THEORY, DIRAC CLASSICAL. See **Dirac classical electron theory.**

ELECTRON TRANSFER. The process of the shifting of an electron from one electrical field to another, as in the formation of an electrovalent bond, in which an electron moving in an orbit about one atom shifts to move in an orbit about the two bonded atoms.

ELECTRON TUBE. See **tube, electron.**

ELECTRON, VACUUM. See **vacuum electron.**

ELECTRON, VALENCE. The electrons in the outermost shell of the structure of an atom. Since these electrons constitute the means by which the atom enters into chemical combinations—either by giving them up, or by adding others to their shell, or by sharing electrons in this shell—these outermost electrons are called valence electrons.

ELECTRON-VOLT. The energy received by an electron in falling through a potential difference of one volt 1 ev is equal to 1.60203 $\times 10^{-12}$ erg. An ev is associated through the **Planck constant** with a photon of wavelength 1 2395 microns.

ELECTRON WAVELENGTH. The wavelength, λ, of the **wave train** which characterizes electrons moving with momentum p. These two quantities are related by the equation $\lambda = h/p$, where h is the **Planck constant.**

ELECTRONEGATIVE ELEMENT. An element which has a relatively great tendency to attract electrons, whereby the **bond energy** of its **linkage** with another and different atom is found to exceed the mean of that found in linkages between the two pairs of identical atoms (i e., the X-Y bond energy exceeds the mean of the values for X-X and Y-Y). Electronegative elements are, generally, acid forming; their outer shell contains four or more electrons, and they tend to add electrons to complete it. They are commonly nonmetals.

ELECTRONEGATIVITY. The extent, relative to other atoms, to which a given atom or group of atoms tends to attract and hold valence electrons in its immediate neighborhood.

ELECTRONIC. Of or pertaining to devices, circuits, or systems utilizing electron devices.

ELECTRONIC BAND SPECTRA. Spectra arising from electronic transitions in molecules.

ELECTRONIC BUG. A **bug** which automatically produces correctly spaced "dots" and "dashes" of the correct length. The circuit is so designed that it is impossible to interrupt a character, or space characters too closely.

ELECTRONIC CHARGE, SPECIFIC. The ratio e/m_e of the electronic charge to the rest-mass of the electron; $e/m_e = 1.759 \times 10^7$ abcoul gm^{-1}.

ELECTRONIC ENERGY OF DIATOMIC MOLECULES. In the *Report on Notation for Spectra of Diatomic Molecules*, Mullikan, *Phys. Rev.* **36**, 623 (1930), the electronic energy is defined as the energy E_e, the total internal energy of a molecule in a definite electron state with the nuclei stationary (this condition may be realized in imagination by making the masses infinite) at their equilibrium distance (r_e) apart. E_e consists of (a) kinetic energy of the electrons, plus (b) their potential energy with respect to the nuclei and to one another, plus (c) the mutual potential energy of repulsion of the two nuclei.

ELECTRONIC MICROPHONE. See **microphone, electronic.**

ELECTRONIC SPECIFIC HEAT. In the original formulation of the **Drude free electron theory of metals,** it was assumed that the electrons formed a classical gas whose specific heat is just $3Nk$ (N being the number of particles, k, **Boltzmann's constant**). No such specific heat was observed, but it was pointed out by Sommerfeld that the electrons should be treated as a **Fermi-Dirac gas,** for which the specific heat per unit volume is given by

$$c_v = \tfrac{1}{2}\pi^2 NkT/T_F$$

where T_F is the **Fermi temperature.** This formula suggests that only the fraction $(\pi^2/6)(T/T_F)$ of the electrons can actually contribute to the specific heat. Since this fraction is of the order of 10^{-3} at room temperatures, the electronic specific heat is negligible compared with the lattice specific heat except at temperatures of a few degrees absolute. In the **band theory of solids** c_v is roughly proportional to the **effective mass** of the electrons.

ELECTRONIC STATES, MANIFOLD OF. See **manifold of electronic states.**

ELECTRONIC SWITCH. An **electron tube** device for alternately switching between two input signals. It consists of two amplifier channels, each fed by one of the inputs, arranged so they are alternately biased to cut-off (i.e., become inoperative) and feeding a common output.

ELECTRONIC THEORY OF VALENCE. The explanation of the nature of chemical **bonds,** i.e., the forces linking atoms to form molecules, as well as certain higher aggregates, in terms of the electrostatic forces between negatively-charged electrons and positively-charged atomic nuclei. Certain differences in characteristics of substances are explained by differences in the method by which these forces are established. Thus the **electrovalent bond** arises in compound formation where there is transfer of an electron from one atom to another, resulting in the formation of oppositely charged ions which attract each other. **Covalent bonds** arise by the sharing of electrons between atoms. Compounds having electrovalent bonds usually ionize and exhibit electrolytic properties; while the covalent bonds are characteristic of organic substances. There are, of course, other types of linkages within these two groups, as well as special or intermediate cases. These statements are general and the ultimate statements of structure must be made in terms of quantitative measurements of bond distances and energies.

ELECTRONIC TUNING. (1) In **reflex klystrons** the alteration of the frequency of oscillation by changing the repeller voltage. (2) Changing the frequency of operation of a transmitter or receiver by changing a control voltage.

ELECTRONIC WATTMETER. See **wattmeter, electronic.**

ELECTRONICS. That field of science and engineering which deals with electron devices and their utilization. Electronic, used as an adjective, signifies of or pertaining to the field of electronics.

ELECTRO-OPTICAL SHUTTER. A device for controlling or cutting off a beam of light by means of the **Kerr electro-optical effect.**

ELECTRO-OSMOSIS, ELECTRO-ENDOSMOSIS. The movement of liquid with respect to a fixed solid (e.g., a porous diaphragm

or a **capillary tube**) as a result of an applied electric field.

ELECTROPHONIC EFFECT. The sensation of hearing produced when an alternating current of suitable frequency and magnitude from an external source is passed through an animal.

ELECTROPHORESIS. The movement of colloidal particles through a fluid under the action of an **electric field.** Positive sols (metallic oxides and hydroxides, basic dyestuffs) migrate to the cathode, and negative sols (metals, sulfur, metallic sulfides, acid dyestuffs) migrate to the anode.

ELECTROPHORESIS BY TISELIUS METHOD. A moving-boundary method for use with colloidal systems. The apparatus is basically of the U-tube variety with the U-tube of rectangular cross section, and built in sections. The lower section of the U-tube is filled with the colloidal solution and the top with pure solvent. The boundary between the two is sharp and stable, and on application of an electric field the boundary moves and is observed by the **Schlieren technique.**

ELECTROPHORETIC EFFECT. Discussed under **theory of electrolytes.**

ELECTROPHORUS. The simplest of all **static machines;** devised by Volta in 1816. It consists of a slab of some resinous substance, such as sealing wax or vulcanite, which is negatively charged by rubbing with fur. A metal plate provided with an insulating handle is placed upon the electrified slab. The contact is localized at a few points, so that instead of taking the negative charge off the slab, the metal plate becomes charged by induction, positively on the under side and negatively on the upper. The negative induced charge is now removed by grounding with the finger, and upon being lifted by means of the handle, the plate becomes positively charged all over, often strongly enough to yield bright sparks. Very little of the negative charge on the slab is removed in this process, and it may thus be used over and over to induce an indefinite number of positive charges.

ELECTROPLATING. The coating of an object with a thin layer of some metal through electrolytic deposition. (See **electroforming.**)

ELECTROPOLISHING. Production of a smooth surface on metals by electrolytic means.

ELECTROSCOPE. An instrument for detecting small charges of **electricity,** or for measuring small voltages, or sometimes, indirectly, very small **electric currents,** by means of the mechanical forces exerted between electrically-charged bodies. One of the earliest sensitive electroscopes consists of two narrow strips of gold-leaf hanging together in a glass jar. Upon being charged, they stand apart on account of their mutual repulsion. One leaf may be replaced by a stiff strip of brass, so that only the remaining leaf can move. The Wilson electroscope has a single gold-leaf which, on being charged, is attracted by a grounded metal plate tipped at such an angle as to give maximum sensitivity.

ELECTROSCOPE, LAURITSEN. A rugged yet sensitive **electroscope** employing a metallized quartz fiber as the sensitive element.

ELECTROSCOPE, WILSON. Discussed under **electroscope.**

ELECTROSOL. A **colloidal solution** produced by electrical means, as by passing a spark between metal electrodes in a liquid.

ELECTROSTATIC ACTUATOR. An apparatus constituting an auxiliary external electrode which permits the application of known electrostatic forces to the diaphragm of a microphone for the purpose of obtaining a primary calibration.

ELECTROSTATIC DEFLECTION. The deflection of an **electron beam** as a result of its passing through an electrostatic field which has a component perpendicular to the path of the beam.

ELECTROSTATIC FIELD. An **electric field** that is constant in time, i.e., an electric field produced by stationary charges. The field at any point is the (vector) sum of the fields (at that point) due to each of the charges. The field is also given by the negative gradient of the **electric potential:**

$$\mathbf{E} = -\nabla\phi.$$

(See **electrostatics, laws of; electric field strength.**)

ELECTROSTATIC FOCUSING. See **focusing, electrostatic; electron lens.**

ELECTROSTATIC GENERATOR. A high-voltage generator in which the potential is produced by the work done in mechanical transport of electric charges. A Van de Graaf generator employing a system of conveyor belt and spray points to charge an insulated electrode to a high potential is an electrostatic generator which may be used to accelerate charged particles to sufficiently high energies to induce **nuclear reactions.**

ELECTROSTATIC LENS. An arrangement of electrodes so disposed that the resulting electric fields produce a focusing effect on a beam of charged particles. (See also **electron lens.**)

ELECTROSTATIC LOUDSPEAKER. See **loudspeaker, electrostatic.**

ELECTROSTATIC MEMORY. A memory device utilizing electrostatic charge as the means of retaining information, involving usually a special type of cathode-ray tube together with associated circuits.

ELECTROSTATIC MEMORY TUBE. An electron tube in which information is retained by means of electric charges. Synonym: storage tube.

ELECTROSTATIC MICROPHONE. See **microphone, electrostatic.**

ELECTROSTATIC POTENTIAL. See **potential, electric.**

ELECTROSTATIC RECIPROCITY THEOREM. See **reciprocity theorem.**

ELECTROSTATIC SHIELDING. See **screening.**

ELECTROSTATIC UNITS. See **esu system of units.**

ELECTROSTATIC VALENCE. The type of **valence** which involves electron transfer. It is also known as ionic valence.

ELECTROSTATIC VOLTMETER. See **electrometer.**

ELECTROSTATIC WATTMETER. See **wattmeter, electrostatic.**

ELECTROSTATICS. While moving **electricity** has certain properties peculiar to its motion (see **electric currents, electromagnetism**), electrostatics is concerned with phenomena exhibited by electricity whether in motion or at rest. The outstanding elements of the subject are electric charges, electric fields, electric induction in conductors, and electric polarization in **dielectrics.**

Owing to the tremendous mutual repulsion of all electricity for electricity of the same kind, it is impossible to gather together any considerable quantity of free electricity, positive or negative, in a limited space. To place a single coulomb of either sign on a metal sphere 10 cm in diameter would require 4.5×10^{17} ergs of energy, equal to the output of a 100-hp motor running continuously for a week; and its sudden release would rival the explosion of a carload of dynamite. But we can collect and experiment with very small charges. It is found that their attractions and repulsions obey the **Coulomb law** of inverse squares, and are also definitely dependent upon the dielectric constant of the surrounding medium. Faraday showed that any charge, imparted to a conductor, at once seeks the outside surface and so distributes itself there as to produce no influence anywhere inside. The **electric potential** of such a conductor is uniform both over its surface and throughout its interior.

The space outside in the neighborhood of the charge is, however, occupied by an electric field, as shown by the fact that a small charged body placed anywhere in it is acted upon by a definite force. Such a field may be mapped out by lines of force as in the case of a **magnetic field.** (See **fields of force.**) The electric intensity at any point of an electric field is measured by the force exerted upon a free unit charge placed at that point, and its direction is that of the force on a positive charge.

If a pair of equal, opposite charges at a fixed distance apart, called an "electric dipole," is placed in an electric field, it experiences in general a torque (like a bipolar magnet in a magnetic field). The maximum torque thus produced by a field of unit intensity is called the "electric moment" of the dipole; its magnitude is the product of either charge by the distance between them.

When a neutral conductor is placed in an electric field, it develops charges on opposite sides, the positive charge being on the side toward which a free positive charge is urged. The conductor has thus acquired an electric moment. This is due to a shifting of the

electrons in the conductor until the region inside the conductor again attains the condition of zero field and uniform potential (see **electric screening**); and the process is called electric induction. The **electrophorus,** for example, utilizes this principle, as do other **static machines.** When a concentrated charge is brought near a large conducting surface, the charge thereby induced on the latter has in some respects the effect of a second concentrated charge, of opposite sign to the first, and lying behind the conducting surface; which gives rise to the idea of an "electric image," sometimes useful in electrostatic calculations.

If the object placed in the electric field is a dielectric or non-conductor, while there is no true induction, something like a stress, called an electric polarization, develops within the dielectric. This condition is the essential feature in the operation of a capacitor, and its existence profoundly affects the **capacitance** of the conductors whose charges are responsible for the field.

ELECTROSTATICS, LAWS OF. The potential at a distance r from a charge q is $\phi = q/\epsilon r$ where ϵ is the absolute **permittivity** (or absolute **dielectric constant**) of the surrounding medium. The potential due to a number of point charges is

$$\phi = \frac{q_1}{\epsilon r_1} + \frac{q_2}{\epsilon r_2} + \frac{q_3}{\epsilon r_3} + \cdots.$$

The potential due to a continuous distribution of charge is given by

$$\phi = \frac{1}{\epsilon}\int \frac{\rho}{r}\,dV$$

where ρ is the charge density. The electric field is given by the negative gradient of the potential; $\mathbf{E} = -\nabla\phi$.

These statements may be derived from either the **Coulomb law** for electric charges or the **Gauss law,** which is equivalent. The **Poisson equation:**

$$\nabla^2\phi = -4\pi\rho/\epsilon$$

follows from them and is the starting point for many electrostatic problems. In the absence of local charges, the Poisson equation reduces to the special case of the **Laplace equation:**

$$\nabla^2\phi = 0.$$

It is here assumed that the surrounding medium is isotropic and homogeneous, and that unrationalized units are employed.

ELECTROSTRICTION. The phenomenon wherein some materials experience an elastic **strain** as the result of an applied electric field, this strain being *independent* of the polarity of the field. (See **electrostrictive effect on crystals.**)

ELECTROSTRICTIVE EFFECT ON CRYSTALS. In addition to the first-order **piezoelectric effect** found only in crystals having particular symmetry properties and being linear in **D**, all crystals have a second-order electrostrictive effect in which a distortion occurs which is proportional to the square of the **electric displacement.** The effect is large in **ferroelectric** crystals, such as barium titanate, and is apparently due to the stresses induced by changing the alignment of the ferroelectric **domains** upon electrification. (Cf **magnetostriction.**)

ELECTROVISCOUS EFFECT. The change in viscosity of a liquid when placed in a strong electrostatic field The effect is very small and occurs only in **polar liquids.**

ELEMENT. (1) A quantity identified by two symbols designating a row and column in an array, such as a **matrix element** or an element of a **determinant.** As used in calculus see **integral, line; surface; volume.** (2) A collection of atoms of one type which cannot be decomposed into any simpler units by any chemical transformation To date 101 different elements are known; these may be grouped into an ascending series according to the **nuclear charge;** some elements (those in the so-called **radioactive series**) spontaneously decompose into simpler elements; radioactive decomposition can be induced artificially where it does not occur in nature and for each element there is known a number of **isotopes,** i.e., atoms with the same nuclear charge but different nuclear masses which may vary within certain limits. There are also instances in which atoms have the same nuclear charge and **nuclear mass,** but differ only in nuclear energetics, and hence stability and behavior. (3) Any electrical device (such as **inductor, resistor, capacitor, generator, line, electron tube,** or **semiconductor**) with terminals at which it may be directly connected to

other electrical devices. (4) An integral part of a device (e.g., of an electron tube or of a semiconductor) which contributes to its operation. (5) A **parameter** in an **acoustical system** which defines a distinct activity in its part of the system.

ELEMENT, ARTIFICIAL RADIOACTIVE. A **radioactive element** produced from another element, or from an **isotope** of the same element, by the bombardment of **protons, neutrons, deuterons, γ-rays,** or other particles or radiations.

ELEMENT NUMBER 99. On February 1, 1954, the Atomic Energy Commission announced the discovery of the element of atomic number 99. The mass number of the nuclide reported is 247, and it resulted from bombardment of atoms of uranium 238 by nitrogen nuclei The report stated that this nuclide is radioactive and short-lived, changing into **berkelium,** and that it is not fissionable.

Element #99 is tentatively named einsteinium.

ELEMENT NUMBER 100. On March 1, 1954, simultaneous announcement was made by Argonne National Laboratories and the University of California of the product of Element #100. Atoms of plutonium of mass number 239 were transmuted in the nuclear reactor, by absorption of 15 neutrons for each atom irradiated to atoms of Element #100 of mass number 254. In the process 6 β-particles are emitted In a separate study Element #100 was produced from Element #99 by irradiation in the materials testing reactor. The half-life of this nuclide of Element #100 is approximately 3 hours, and it decays by emission of α-particles of approximately 7 2 mev energy. Its properties are similar to those of the earlier actinide elements.

Element #100 is tentatively named fermium.

ELEMENT NUMBER 101. See **mendelevium.**

ELEMENT, RADIOACTIVE. An element that disintegrates spontaneously with the emission of various rays and particles. Most commonly the term denotes radioactive elements such as radium, radon (emanation), thorium, promethium, uranium, which occupy a definite place in the periodic table because of their atomic number. The term radioactive element is also applied to the various other nuclear species (which are produced by the disintegration of radium, uranium, etc.) including the members of uranium, actinium, thorium, and neptunium families of radioactive elements, which differ markedly in their stability, and are isotopes of elements from thallium (atomic number 81) to uranium (atomic number 92), as well as the partly artificial actinide group, which extends from actinium (atomic number 89) to californium (atomic number 98), and includes the transuranic elements neptunium (atomic number 93), plutonium (atomic number 94), americium (atomic number 95), curium (atomic number 96), berkelium (atomic number 97), californium (atomic number 98), element number 99, element number 100, and element number 101 (mendelevium). The radioactive nuclides produced from nonradioactive ones are discussed under **element, artificial radioactive.**

ELEMENT RADIOACTIVE, COLLATERAL SERIES. In addition to the three main natural and one artificial disintegration series of radioelements, each has been found to have at least one parallel or collateral series. The main series and the collateral series have different parents, but become identical in the course of disintegration, when they have a member in common.

ELEMENTAL AREA. See **picture element.**

ELEMENTARY CHARGE. See **electron.**

ELEMENTARY PARTICLE. Originally this term was applied to any particle of matter which was considered to have a unique set of intrinsic properties and a permanent and independent existence. It has since been found that certain of these particles can convert into one or more other particles, or to radiation. Therefore the term elementary particle is now applied quite loosely to the electron, positron, neutron, proton, the various mesons, the hyperons, the neutrino and to other particles that are under investigation or whose existence has been postulated. Photons are commonly included, even though their intrinsic properties, such as spin and parity,

are not fixed, but depend on the radiation field they represent.

ELEMENTARY QUANTUM OF ACTION. See **Planck constant.**

ELEVATOR COIL. The name sometimes applied to the impedance-matching, input transformer in a television receiver.

ELIMINATION BAND. See **stop band.**

ELLIPSE. A **conic section** obtained by a cutting plane parallel to no element of a right circular **conical surface.** It is the **locus** of a point which moves so that the sum of its distances from two foci is a constant. Its **eccentricity** is less than unity. The standard equation may be taken as

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1.$$

The curve is a **central conic** for it is symmetric about both the X- and Y-axes When placed in this standard position, the center of the ellipse is the coordinate origin, the **major axis** of length $2a$ is along the X-axis, and the **minor axis** of length $2b$ is along the Y-axis. The distance from the center to either **focus** is $\sqrt{a^2 - b^2}$, the **eccentricity** e is given by $ae = \sqrt{a^2 - b^2}$; the length of the **latus rectum** is $2b^2/a$; the equations for the **directrices** are $x = +a/e$. The distance from any point on the ellipse to a focus is a **focal radius** and the sum of two focal radii equals $2a$.

If the semi-major axis equals the semi-minor axis ($a = b$), the ellipse degenerates into a circle.

ELLIPSOID. A **central quadric,** given in its standard form, with center at the coordinate origin, as

$$\frac{x^2}{a_2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1$$

where a, b, c are the semi-axes. Sections parallel to each of the coordinate planes are **ellipses.**

If two of the axes become equal, the surface is a **spheroid,** which can be generated as a **surface of revolution.** Consider an ellipse in the XZ-plane

$$\frac{x^2}{a^2} + \frac{z^2}{c^2} = 1$$

with $a > c$, so that its major axis is along the X-axis of the coordinate system and its minor axis along the Z-axis. There are then two possibilities: (1) rotate the ellipse about its major axis and the result is a **prolate spheroid** with $a > b = c$; (2) rotate about the minor axis and obtain an **oblate spheroid,** $a = b > c$. Sections through the surface are circles in both cases: when taken parallel to the plane $x = 0$ for the prolate case; parallel to $z = 0$ for the oblate case.

In the final degenerate case, $a = b = c$, the surface is a **sphere.**

ELLIPSOID, MOMENTAL (ELLIPSOID OF POINSOT). For a rotating body with no resultant external torque acting on it

$$\boldsymbol{\omega} \cdot \mathbf{H} = 2T$$

where **H** is the vector angular momentum, $\boldsymbol{\omega}$ is the resultant vector angular velocity and T is the total kinetic energy When expressed in component form, this becomes the equation of an ellipsoid in angular velocity space.

$$I_{xx}\omega_x^2 + I_{yy}\omega_y^2 + I_{zz}\omega_z^2 = 2T.$$

I_{xx}, I_{yy} and I_{zz} are the moments of inertia with respect to the principal axes fixed in the body. ω_x, ω_y, ω_z are the components of angular velocity with respect to the principal axes fixed in the body. The length of the radius vector from the origin to the surface of the ellipsoid represents a value of the angular speed consistent with the total kinetic energy and angular momentum. (See **inertia, momenta and products of; rigid body, kinetic energy of.**)

ELLIPSOIDAL COORDINATE. A system based on confocal quadrics. If λ, μ, ν are the three real roots of a cubic equation in a parameter describing such quadrics, they also locate the position of a point in space, for three mutually perpendicular quadric surfaces intersect at the point. If constants are taken so that $a > b > c$, the surfaces are: (1) **ellipsoids,** λ = const., $c^2 > \lambda > -\infty$; (2) **hyperboloids** of one sheet, μ = const., $b^2 > \mu > c^2$; (3) hyperboloids of two sheets, ν = const. $a^2 > \nu > b^2$.

The relation between the rectangular Cartesian coordinates and the ellipsoidal coordinates of a point are

$$x^2 = \frac{(a^2 - \lambda)(a^2 - \mu)(a^2 - \nu)}{(a^2 - b^2)(a^2 - c^2)}$$

$$y^2 = \frac{(b^2 - \lambda)(b^2 - \mu)(b^2 - \nu)}{(b^2 - a^2)(b^2 - c^2)}$$

$$z^2 = \frac{(c^2 - \lambda)(c^2 - \mu)(c^2 - \nu)}{(a^2 - c^2)(b^2 - c^2)}.$$

Since x, y, z occur as squares in these relations they give eight points symmetrically located in the Cartesian system. Some convention must then be adopted for the signs of the ellipsoidal coordinates in order to locate a point uniquely.

These coordinates are also frequently called **elliptical** but that term is best reserved for a two-dimensional system of confocal conics. Most of the curvilinear systems used in mathematical physics (including rectangular and spherical polar coordinates) are degenerate cases of the ellipsoidal system.

ELLIPTIC. See **function, elliptic; integral, elliptic.**

ELLIPTIC(AL) COORDINATE. Often used to mean an **ellipsoidal coordinate** but more correctly the two coordinates locating a point in a plane, when referred to a system of **confocal conics.**

ELLIPTIC CYLINDRICAL COORDINATE. A degenerate case of **ellipsoidal coordinates** where the surfaces are: (1) **elliptic cylindrical** with semi-axes $a = c \cosh u$, $b = c \sinh u$, $u =$ const.; (2) **hyperbolic cylindrical** with $a = c \cos v$, $b = c \sin v$, $v =$ const.; (3) planes parallel to the XY-plane, $z =$ const. A point in this system has rectangular Cartesian coordinates

$$x = c \cosh u \cos v$$

$$y = c \sinh u \sin v$$

$$z = z$$

and $0 \leq u \leq \infty$; $0 \leq v \leq 2\pi$; $-\infty < z < \infty$.

ELLIPTIC PARTIAL DIFFERENTIAL EQUATION. A special case of the general **partial differential equation** where $A(x,y)C(x,y) > B^2(x,y)$ for all x,y. The **characteristic curves** become complex functions. Writing $\lambda = (u + iv)$, the other solution is $\mu = (u - iv)$ and the **normal form** of the equation is

$$\frac{\partial^2\psi}{\partial u^2} + \frac{\partial^2\psi}{\partial v^2} = \rho(u,v)\frac{\partial\psi}{\partial u} + T(u,v)\frac{\partial\psi}{\partial v} + U(u,v)\psi.$$

The specification of **Dirichlet** or **Neumann** conditions along a closed boundary assures a unique solution. The **Laplace, Helmholtz,** and **Poisson** equations are of elliptic type.

ELLIPTICALLY-POLARIZED LIGHT. See **light, elliptically-polarized.**

ELLIPTICALLY POLARIZED SOUND WAVE. See **sound wave, elliptically polarized.**

ELLIPTICALLY POLARIZED WAVE. See **wave, elliptically polarized.**

ELONGATION. The increase in length along the direction of application of a stress.

EMANATING POWER. The fraction of radioactive inert-gas atoms formed in a solid or solution that escape.

EMANATION. A name often given to element 86. The nomenclature has not been settled definitely. The names radon and emanon are also used. The naturally occurring isotopes of mass 219, 220 and 222 are known as actinon, thoron, and radon, respectively. The longest-lived isotope has a **mass number** of 222, and a half-period of 3.825 days.

EMANON. See **emanation.**

EMBOSSED GROOVE RECORDING. A method of disk recording which employs a comparatively blunt stylus to push aside the material in the modulated groove. No material is removed from the disk. Frequently employed in dictating machines because the disks can be heated and reused, and also because there is no refuse to be cleaned away during the recording operation.

EMBRITTLEMENT. An increase in the susceptibility of a metal to fracture under stress caused by the introduction of gas or other foreign atoms, by segregation of brittle constituents, by internal oxidation, or by certain types of corrosion.

EMINENCE. See **anticyclone.**

EMISSION CHARACTERISTIC. A relation, usually shown by a graph, between the emission and a factor controlling the emission

(such as temperature, voltage, or current) of a filament or heater.

EMISSION, FIELD. Electron emission from solids or liquids resulting directly from a high potential-gradient at their surface.

EMISSION, PHOTOELECTRIC. Electron emission from solids or liquids resulting directly from bombardment of their surface by **photons.**

EMISSION, SECONDARY. See **secondary emission.**

EMISSION, THERMIONIC. See **thermionic emission.**

EMISSIVE POWER. The emissive power of a body is equal to its **absorptive power** multiplied by the emissive power of a black body at the same temperature. The emissive power of a black body (perfect or complete radiator) is the total radiation from the black body per unit area of radiating surface.

EMISSIVITY. The ratio of the radiation emitted by a surface to the radiation emitted by a **complete radiator** (black body) at the same temperature and under similar conditions. The emissivity may be expressed for the total radiation of all wavelengths (total emissivity), for visible light (luminous emissivity) as a function of wavelength (spectral emissivity) or for some very narrow band of wavelengths (monochromatic emissivity). Excepting for luminescent materials, the emissivity can never be greater than unity.

EMITRON. A type of television **camera tube.**

EMITTANCE. The radiant emittance of a source is the power radiated per unit area of the surface. This may be either the radiant emittance per unit range in wavelength, the spectral radiant emittance, or its integral over all wavelengths, the total radiant emittance. If the radiant emittance is evaluated by the standard luminosity function, it is called luminous emittance. For a perfectly diffusing surface, the luminous emittance is equal to π times the **intensity luminance.**

EMITTER (OF A TRANSISTOR). See **emitter, majority** and **emitter, minority.**

EMITTER, MAJORITY (OF A TRANSISTOR). An **electrode** from which a flow of **majority carriers** enters the **interelectrode region.**

EMITTER, MINORITY (OF A TRANSISTOR). An electrode from which a flow of **minority carriers** enters the interelectrode region.

EMITTER RESISTANCE, TRANSISTOR. See **transistor parameter r_e.**

EMMETROPIC EYE. An eye in which light from a distant object is focused exactly at the retina when accommodation is entirely relaxed.

EMPHASIZER. A **filter** used in an audio system to emphasize some portion of the frequency spectrum.

EMPIRICAL MASS FORMULA. See **mass formula, empirical.**

EMPTY MAGNIFICATION. If the image formed by a telescope or microscope is not magnified enough, some detail of the object which is resolved by the instrument may not be seen by the eye. The detail may be correctly represented in the image formed by the instrument, but its size in that image may be so small that it cannot be resolved by the eye. Magnification which gives an image up to the size such that each detail resolved by the instrument shall be large enough to be resolved by the eye is useful magnification. Any magnification in excess is called empty magnification since it does not reveal any fresh detail in the object.

EMU. An abbreviation for any electrical unit in the **emu system of units.** Now obsolescent, having been replaced by the prefix ab- attached to the name of a unit in the practical system. E.g., abampere, abvolt.

EMU SYSTEM OF UNITS. A system of electrical units based on the choice of the **permeability** of empty space as unity and dimensionless. The units are usually denoted by the prefix ab- attached to a unit name in the practical system E.g., abcoulomb, ab ohm. (See Introduction.)

EMULSIFICATION. The process of preparing an **emulsion.**

EMULSIFICATION, THEORY OF. A theory to explain the formation of oil-in-water and water-in-oil **emulsions.** It is found experimentally that alkali-metal soaps when used as emulsifying agents tend to give oil-in-water emulsions while heavy-metal soaps give water-in-oil emulsions. According to Bancroft the emulsifying film may be considered as three molecules thick, consisting of an oil molecule, an emulsifying agent molecule and a water molecule. When the **interfacial tension** at the water-emulsifying agent interface is less than at the oil-emulsifying agent interface, the film tends to bend and becomes convex on the water side forming an oil-in-water emulsion, and vice versa. Harkins proposed an "oriented wedge" theory of emulsions. This stated that for soaps such as the monovalent soaps for which the cross section of the metal ion is smaller than the paraffin chain, the emulsion would be of the oil-in-water type so as to form an interfacial film of the greatest density, and vice versa. There are, however, a number of exceptions to this theory.

When solid powders are used as emulsifying agents, if the solid is preferentially wetted by one phase, then since the powder tends to be taken up at the interface, more particles can pack into the interface if this is curved and convex to that phase Thus if the powder is wetted more strongly by water then oil-in-water emulsions will tend to be formed This may be regarded as an extension of the Bancroft theory.

EMULSION. A lyophobic **colloid** system in which the particles making up the internal phase (dispersed phase) consist of globules of a liquid which is immiscible with the liquid external phase (dispersion medium).

ENANTIOMORPHS. Crystals that possess neither a plane nor a center of **symmetry** and cannot be brought into coincidence with their reflected image. They are distinguished as right and left forms and commonly exhibit optical activity, the right and left forms rotating the ray of polarized light in opposite directions. (Cf. **isomerism, optical.**)

ENANTIOTROPY. The property possessed by a substance of existing in two crystal forms, one stable below, and the other stable above, a certain temperature called the **transition point.**

ENCLODYNE RECEPTION. See **autodyne reception.**

END-FIRE ARRAY. See **array, end-fire.**

END PRODUCT. The final product of a reaction or process. In **radioactive series,** the stable nuclide constituting the last member of the series.

END SHIELD. Shield placed at either end of the interaction space of a **magnetron** to prevent electrons from bombarding the end seals.

ENDOERGIC. The same as endothermic, i.e., requiring input of heat or energy. (See **disintegration energy, nuclear.**)

ENDOSMOSIS. A type of **osmosis** in which the solvent dialyzes into the system. Exosmosis is the reverse process. The two processes may be illustrated by the conditions in the living cell; when the plasma is hypertonic, solvent passes from the cell into the plasma (exosmosis); when the plasma is hypotonic the solvent passes from the plasma into the cell (endosmosis).

The movement of the liquid relative to colloidal particles under an applied electrical field is termed **electro endosmosis.**

ENDOTHERMIC. Characterized by the absorption of heat Endothermal reactions absorb heat as they progress. An endothermal cell is an electrical cell in which the production of a current is attended by an absorption of heat.

ENERGY. Energy is often defined as the ability to do work. Thus, a capacitance of magnitude C, carrying a charge Q, possesses electrical energy in the amount $Q^2/2C$, and can do this much work in the process of being discharged. In this instance, the energy is considered to reside in the electric field between the plates of the capacitor. In other cases, e.g., that of **kinetic energy,** the energy is considered to reside in the body itself. The mechanical or electrical energy of a system is always measured as the maximum amount of work that the system can do in coming to static equilibrium.

When other forms of energy than electrical or mechanical are concerned (e.g., thermal

or chemical energies) the elementary definition is not completely satisfactory, since the amount of work that can be done depends on the surroundings as well as on the state of the body. In such cases, the definition given above is that of the **free energy,** and the total energy is better defined as the maximum amount of work that the system can do in coming to static equilibrium at the absolute zero of temperature. Even this definition breaks down, however, if the system possesses **zero point energy.**

In special relativity, energy and mass are equivalent being connected by the Einstein equation $E = mc^2$ where c is the speed of light. Hence, when relativistic mechanics must be applied, e g , when speeds comparable to c are involved, the energy of a system includes the rest energy m_0c^2 of all the bodies in the system. Here m_0 is the mass of a body at rest with respect to the other bodies of the system and to the observer

Energy is particularly important because it is a conserved quantity, which can be neither created nor destroyed. It may, however, be exchanged among various bodies or may be converted from one form to another, or interconverted with mass as in the Einstein equation above (See also **work; conservation of energy, law of.**)

ENERGY, AVAILABLE. See **available energy.**

ENERGY BAND. A continuous range of energies in which there exist **energy levels.** Usually shortened to **band.**

ENERGY, BINDING. There are a number of definitions for this term. (See **binding energy; binding energy, electron; binding energy, proton; binding energy, nuclear;** etc.)

ENERGY, COHESION. The energy which would be required to break up a solid or liquid into its constituent atoms or molecules. The cohesion energy is often expressed as the energy per mole of a body of such extent that the surface energy is negligibly small.

ENERGY, CONSERVATION OF. (1) General—An accepted principle which states that energy can never be created or destroyed, but can only be changed in form, as discussed in the entry on **energy** and **conservation of energy, law of the.** (2) For a conservative mechanical system—If all the forces acting on the system are conservative forces, the total mechanical energy of the system is constant, and equal to the sum of the potential and kinetic energies. (See **conservative system;** and **energy integral.**)

ENERGY CONTOUR. A contour of constant energy, mapped out on a diagram whose coordinates are some physical parameters of a system, or which define various states of the system, as for example the energy of an electron in a metal as a function of its **crystal momentum.**

ENERGY, DEGRADATION. Changes in form of **energy** take place in the direction of increasing **entropy,** hence lesser availability.

ENERGY, DISGREGATION. The energy a body possesses by virtue of the tendency of its particles to repel each other.

ENERGY DISSIPATION RATE, ACOUSTIC. The rate at which the energy in a sound wave is dissipated into heat energy.

ENERGY, FREE. See **free energy.**

ENERGY GAP (OF A SEMICONDUCTOR). The energy range between the bottom of the **conduction band** and the top of the **valence band.** (See also **forbidden band.**)

ENERGY INTEGRAL. The first integration of the **Newton equation of motion** $m\ddot{\mathbf{r}} = \mathbf{F}$, in which $\mathbf{r}$ is the position vector of the particle of mass m and $\mathbf{F}$ is the resultant (vector) force acting in it, yields an integral of the form

$$\tfrac{1}{2}mv^2 - \int \mathbf{F}\cdot d\mathbf{r} = C$$

where v is the velocity at any instant and C is a constant of integration. This is usually called the energy integral, since $\frac{1}{2}mv^2$ is the kinetic energy. If $\mathbf{F}$ is a conservative force $-\int \mathbf{F}\cdot d\mathbf{r}$ depends only on the position of the particle and is therefore called the potential energy. The constant C becomes the total energy and the existence of the energy integral implies the conservation of mechanical energy.

ENERGY, INTERNAL. See **internal energy.**

ENERGY, KINETIC. The most obvious way in which a body can manifest **energy is to be**

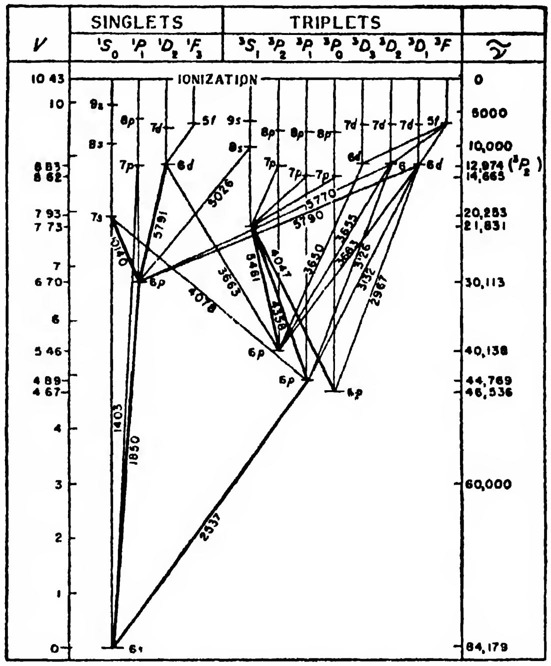
in motion. Experience impels us to get out of the way when we see a rapidly moving, massive object approaching. We know that the more massive it is, and the faster it moves, the more work (and the more damage) it will do when it strikes. A simple course of reasoning based on **Newton's laws of motion** leads to the formula $E = \frac{1}{2}mv^2$ for the kinetic energy (in absolute units) of a mass m moving with a speed v. Thus a stone of mass 100 grams moving with a speed of 1000 cm per sec has $\frac{1}{2} \times 100$ g $\times$ 1000^2 cm^2/sec^2 = 50,000,000 g cm^2/sec^2 (or ergs) of kinetic energy. When the moving body is brought to rest by a force of average value f, and continues to move a distance, d, after this force is applied, it does an amount of work, fd, equal to its kinetic energy $\frac{1}{2}mv^2$. If d is very small, f must be large. Thus, if the stone in the above example were stopped in a space of 0.01 cm (as in striking a hard obstacle), we should have 0.01 cm $\times f$ = 50,000,000 g cm^2/sec^2, or f = 5,000,000,000 g cm/sec^2 (or dynes), which is equivalent to 5100 kilograms or more than 5.6 tons.

The kinetic energy of a body rotating with angular speed ω (radians per sec) about an axis for which its moment of inertia is I, is $E = \frac{1}{2}I\omega^2$; or $2\pi^2In^2$, where n is the number of rotations per sec. The theory of **relativity** gives slightly higher values for the kinetic energy, but the differences are negligible except for very great speeds.

ENERGY, LATTICE. The potential energy of a **crystal lattice**, which is a measure of the stability of the atomic or ionic lattice system.

ENERGY LEVEL. A **stationary state** of energy of any physical system. The existence of many stable, or quasi-stable states, in which the energy of the system stays constant for some reasonable length of time, is an essential characteristic of quantum-mechanical systems, and is the basis of large areas of modern physics.

ENERGY LEVEL DIAGRAM. In general terms, any diagram in which the energies of states of a system, or of parts of a system, are shown by the distances of a series of horizontal lines from a zero level. Such diagrams are of the greatest value in all branches of physics, e.g., **band schemes**, nuclear energy levels, etc.



Energy level diagram for mercury

ENERGY, LUMINOUS. The value of radiant energy (see **energy, radiant**) in terms of its ability to produce **brightness.**

ENERGY, MECHANICAL. For a conservative dynamical system the mechanical energy is the invariant of the motion which is equal to the sum of the kinetic energy (see **energy, kinetic**) and the potential energy (see **energy, potential**). This invariant or constant results from a first integration of the equations of motion and the first integral is usually known as the **energy integral.** Strictly speaking the mechanical energy does not exist for a non-conservative system. However, the concept is so useful that it is customary to treat a dissipative system (see, for example, **forced oscillator with dissipation**) as a system whose energy (defined for the equivalent non-dissipative system) decreases with the time. This makes possible an important connection with non-mechanical forms of macroscopic energy, for example, heat.

ENERGY-MOMENTUM TENSOR. Set of 16 quantities, not necessarily all different, which specify the energy density, momentum density and stresses in a distribution of matter or radiation, and which transform as a tensor. Once the **Lagrangian** L describing a system of fields ψ_a has been specified, an energy-mo-

mentum tensor given by

$$T_{\mu\nu} = L\delta_{\mu\nu} - \sum_a \frac{\partial\psi_a}{\partial x_\nu} \cdot \frac{\partial L}{\partial\left(\frac{\partial\psi_a}{\partial x_\mu}\right)}.$$

Other energy-momentum tensors may be defined, differing from this by a divergence.

ENERGY OF A CHARGED SYSTEM. If the charges q_i are varied on a set of conductors at potentials V_i, the resulting change of energy of the system is given by

$$dU = \sum_i V_i dq_i.$$

Expressed in terms of coefficients of potential (see **potential, coefficients of**)

$$dU = \sum_i \sum_j p_{ij} q_j dq_i$$

which yields upon integration

$$U = \tfrac{1}{2} \sum_i \sum_j p_{ij} q_i q_j = \tfrac{1}{2} \sum_i V_i q_i$$

$$= \tfrac{1}{2} \sum_i \sum_j c_{ij} V_i V_j$$

where the c_{ij} are the coefficients of induction (See **induction, coefficients of.**)

ENERGY OF A SYSTEM OF CURRENT CIRCUITS. The magnetic fluxes through a set of circuits carrying steady currents I_j can be written

$$\phi_i = \sum_j M_{ij} I_j$$

where the $M_{ij} = M_{ji}$ are the **mutual inductances,** and $M_{ii} = L_i$ is the **self-inductance** of the ith circuit. If the circuits are of constant length, i.e., they may be non-rigid, but have no sliding contacts, the induced emf's are

$$\mathcal{E}_i = -d\phi_i/dt$$

$$= -\sum_j M_{ij} dI_j/dt - \sum_j I_j dM_{ij}/dt.$$

Establishing the currents requires doing work at the rate

$$\frac{dW}{dt} = -\Sigma I_i \mathcal{E}_i$$

hence

$$dW = -\Sigma I_i \mathcal{E}_i dt$$

$$= \Sigma\Sigma M_{ij} I_i dI_j + \Sigma\Sigma I_i I_j dM_{ij}$$

If the circuits are held stationary so that no mechanical work is done, the work becomes stored energy of the system, and

$$dU = \Sigma\Sigma M_{ij} I_i dI_j$$

$$U = \tfrac{1}{2}\Sigma\Sigma M_{ij} I_i I_j.$$

ENERGY, POTENTIAL. The negative of the work done by the forces of a conservative system when the particles of the system move from one configuration to another is the potential energy of the second configuration relative to the first configuration. This quantity is independent of the path followed by the particles in changing their configuration and is a function of the initial and final positions only.

An equivalent definition states that the potential energy is that particular function of the coordinates $V(x,y,z)$ whose negative gradient exists and is equal to the force, i.e.,

$$\mathbf{F} = -\nabla V.$$

The existence of V implies a conservative force field

If the force between two particles separated by a distance r is given by $F = K/r^2$, the mutual potential energy of the particles when separated by a distance r is

$$-\int_{r_0}^{r} \frac{K}{r^2} dr,$$

where r_0 is the distance of separation in the initial or standard configuration. For convenience, r_0 is often taken as infinity, in which case the potential energy at infinity is considered to be zero and the potential energy of the final configuration is then K/r. Actually the numerical value of the potential energy is arbitrary because the initial configuration can be chosen arbitrarily. Any constant can be added to the potential energy function and the condition $\mathbf{F} = -\nabla V$ will still be satisfied.

A particle on the surface of the earth is acted upon by a force of mg dynes where m is the mass in grams and g is the acceleration of gravity in cm per sec^2 at the particular point. If the particle is raised a height h centimeters above the surface of the earth, where h is small in comparison with the radius of the earth, the potential energy of the particle with respect to the earth's surface becomes mgh ergs. For example, a 10 gram mass at a distance of 100 cm above the ground has a potential energy of about (10) (100) (980) = 980,000 ergs. If the mass were al-

lowed to fall to the ground in a vacuum, the potential energy would be converted completely into 980,000 ergs of kinetic energy, thus exemplifying the **conservation of energy.** (See also **conservative force.**)

ENERGY, RADIANT. Energy which is transferred by electromagnetic waves without a corresponding transfer of matter.

ENERGY, SURFACE. The energy per unit area required to increase the surface of a solid or liquid, e.g., by cleavage of the solid. The magnitude of the surface energy at a liquid-gas, liquid-liquid or liquid-solid interface is closely related to the **surface tension** of the liquid on that interface.

ENERGY THEOREMS OF ELECTROMAGNETISM. See **Poynting theorem.**

ENERGY, UNITS OF.

1. Absolute System.
   a. Metric—cm gm sec.
      The unit of energy is the **erg** which is the work done by a force of one dyne in moving a distance of one centimeter.
   b. Metric—m kgm sec.
      The unit of energy is the **joule** which is the work done by a force of one newton moving a distance of one meter. One joule = 10^7 ergs.
   c. English—ft lbm sec.
      The unit of energy is the foot-poundal which is the work done by a force of one **poundal** moving a distance of one foot.
2. Gravitational System.
   a. English—lb-force ft sec.
      The unit of energy is the **foot-pound** which is the work done by a force of one pound (force) moving a distance of one foot.

ENFORCED DIPOLE MOMENT. See **forbidden lines (Item 4).**

ENGINE EFFICIENCY. The ratio of the amount of work obtained from the engine to the amount of heat put in, the two quantities being measured in the same units.

ENGLER VISCOSIMETER. See **viscosity, measurement of.**

ENHANCED LINE. A spectral line from a spark or other very hot source whose intensity is out of proportion with that of other lines as compared with an arc or a flame spectrum.

ENRICHMENT. Any process which changes the **isotopic ratio**; in reference to uranium, it is a process which increases the ratio of U-235 to U-238 in uranium by separation of isotopes. Enrichment processes include **thermal diffusion, gaseous barrier diffusion,** and **centrifugal** and **electromagnetic separation.**

ENRICHMENT FACTOR. The ratio of **isotopic ratios** after **enrichment** to that before enrichment.

ENTHALPY. A thermodynamic concept defined by the equation $H = E + PV$ where H is the enthalpy, E is the energy, P the pressure, and V the volume of a system. At constant pressure the change in enthalpy measures the quantity of heat exchanged by the system with surroundings.

ENTLADUNGSSTRAHLEN. Radiation from spark discharges in the wavelength region 400–1000 Å.

ENTRANCE-PORT, EXIT-PORT. Same as **entrance** and **exit pupil** of an optical instrument.

ENTRANCE PUPIL. The image of the **aperture stop** as viewed from the object.

ENTRANCE SLIT. A narrow slit in an opaque screen through which light enters a spectrometer. The spectrum formed is the image of this slit in each wavelength of light present. A narrow slit is necessary for good resolution to avoid great overlapping of these images. However the smaller the entrance slit, the less radiation enters the spectrometer Hence a slit vidth must be used which is a compromise between the resolution desired and the necessary light intensity for proper observation or detection.

ENTROPY. (1) In the mathematical treatment of thermodynamic processes there occurs very often a quantity, now relating energy to absolute temperature, now associated with the **probability** of a given distribution of **momentum** among molecules, and again expressing the degree in which the energy of a system has ceased to be **available energy.** Its mathematical form suggests that these are all aspects of a single physical magnitude. Application of the "second law" of **thermo-**

dynamics leads to the conclusion that if any physical system is left to itself and allowed to distribute its energy in its own way, it always does so in a manner such that this quantity, called "entropy," increases; while at the same time the available energy of the system diminishes. This law applies to the universe as a whole, hence the proposition that the total entropy increases as time goes on. An interesting conclusion as to entropy in the vicinity of absolute zero is expressed by the Nernst heat theorem; viz., that all physical and chemical changes in this region take place at constant entropy. Any process during which there is no change of entropy is said to be "isentropic." This is true, for example, of an **adiabatic process** in which there is no dissipation of energy, i.e., one which is also a **reversible process.** In thermodynamic discussions entropy is commonly classed, along with temperature, pressure, and volume, as one of the variables defining the state of a body, and is often graphed as such on thermodynamic diagrams.

(2) In information theory, entropy is a measure of the uncertainty of our knowledge

ENTROPY, COMMUNAL. See **communal entropy.**

ENTROPY OF DISORDER. That part of the **entropy** of a substance that is due to a disordered arrangement of the molecules as opposed to a similar but ordered arrangement. The most clear-cut example is the **order-disorder transition** in binary alloys, in which virtually the whole entropy change is of this kind. The entropy change on fusion of a solid is largely due to entropy of disorder.

ENTROPY OF FUSION. The unavailable energy during a **fusion,** which is the quantity obtained when the heat absorbed in the conversion of a given substance from the solid to the liquid state is divided by the temperature at which the process takes place.

ENTROPY OF IONS, STANDARD. See **ion(s), standard entropy of.**

ENTROPY OF MIXING. The unavailable energy of a mixture, defined as the difference between the **entropy** of the mixture and the sum of the entropies of the **components** of the mixture.

ENTROPY OF SOLUTION. The **heat of solution** minus the **free energy** of solution.

ENTROPY OF VAPORIZATION. The increase in **entropy** of a substance on changing from the liquid to the vapor state.

ENTROPY, STANDARD. The total **entropy** of a substance in a state defined as standard. Thus, the standard states of a solid or a liquid are regarded as those of the pure solid or the pure liquid, respectively, and at a stated temperature. The standard state of a gas is at 1 atmosphere pressure and specified temperature, and its standard entropy is the change of entropy accompanying its expansion to zero pressure, or its compression from zero pressure to 1 atmosphere. The standard entropy of an ion is defined in a solution of unit activity, by assuming that the standard entropy of the hydrogen ion is zero.

ENTROPY VECTOR. The **four-vector** obtained by multiplying the proper entropy density by the local **four-velocity** in the relativistic theory of classical thermodynamics.

ENTROPY, VIRTUAL. See **virtual entropy.**

ENVELOPE. A curve that is **tangent** to each of a given family of curves. The **envelope** of the family of curves $f(x,y,t) = 0$, where t is the variable **parameter** of the family, is given by the pair of equations

$$f(x,y,t) = 0; \frac{\partial f}{\partial t} = f_t(x,y,t) = 0.$$

These parametric equations of the envelope may be used to eliminate the parameter.

ENVELOPE DELAY. The time of propagation, between two points, of the envelope of a wave. It is equal to the rate of change (first derivative) with angular frequency of the difference in phase between these two points. It has significance over the band of frequencies occupied by the wave, only if this rate is approximately constant over that band.

ENVELOPE DEMODULATOR. See **demodulator, envelope.**

EÖTVÖS EQUATION. A relation for the rate of change of **molar surface energy** with temperature of liquids. Ideally, this quantity

$$k = -\frac{d[\gamma(Mv)^{2/3}]}{dT}$$

should be a constant for all liquids. Actually, deviations are frequently encountered. In the above relationship, γ is the **surface tension** of the liquid, v is its **specific volume,** M is its molecular weight, T is temperature, and k is, ideally, a constant for all liquids.

EPICADMIUM. Neutron energies above the **cadmium cut-off** (about 0.3 ev).

EPITAXY. Oriented **intergrowth** between two solid phases. The surface of one crystal provides, through its lattice structure, preferred positions for the deposition of the second crystal.

EPITHERMAL NEUTRON. See **neutron, epithermal.**

EPOCH ANGLE. See definition under **oscillator, harmonic.**

EPSILON. (1) Dielectric coefficient or capacitivity (ϵ). (2) Permittivity (ϵ). (3) Permittivity of free space (ϵ_0). (4) Relative permittivity (ϵ_r). (5) Emittance (ϵ). (6) Emissivity (ϵ'). (7) Total emissivity (ϵ' or ϵ'_t). (8) Spectral emissivity (ϵ'_λ) (9) Extinction coefficient (ϵ). (10) Self-energy (ϵ). Luminous energy (ϵ). (11) Natural logarithmic base (ϵ but e is preferred). (12) Epoch angle (ϵ) (13) Eccentricity (ϵ or e).

EQUAL-ENERGY SOURCE. A **light** source for which the time rate of emission of energy per unit of wavelength is constant throughout the spectrum.

EQUALITY. A statement that two mathematical expressions are equal. Equalities are of two kinds: identical equalities or **identities,** and conditional equalities or **equations.**

EQUALIZATION. See **frequency-response equalization.**

EQUALIZER. A **network** inserted in a system to modify the overall frequency response in a desired manner. This term is also used for the series of connections made in paralleled, cumulatively-compound d-c generators to prevent system instability.

EQUALIZER, DELAY. See **delay equalizer.**

EQUALIZER, LINE. An **equalizer** inserted in a transmission line to modify the frequency response in a desired manner.

EQUALIZING PULSES. See **pulses, equalizing.**

EQUALIZING SIGNALS. In television, a series of six pulses before and after a serrated, vertical pulse. The action of these pulses causes the vertical deflection to start at the same time in each interval. (See **pulses, equalizing.**)

EQUALLY TEMPERED SCALE. See **scale, equally tempered.**

EQUATION. An equality involving two or more **functions.** Equations are classified by terms describing the functions in them or may be given the name of a mathematician who discovered or studied the equation. (See also **differential equation; integral equation.**)

EQUATION, CUBIC. An algebraic equation of the third degree in one or more variables. If there is one variable, the general form is

$$ax^3 + bx^2 + cx + d = 0$$

where a, b, c, d are constants and x is the variable.

EQUATION, DIFFERENCE. An equation connecting values of an unknown function at two or more equally spaced values of the independent variable, as, for example,

$$u(x + h) - u(x) = 2x + 1,$$

or

$$u(x + 2h) + 2xu(x + h) - u(x) = x^2.$$

A linear difference equation is one in which the unknown linear function occurs linearly and the coefficients are functions of the independent variable only. A homogeneous difference equation contains no term independent of the unknown function u.

EQUATION, HOMOGENEOUS. See **equation, linear.**

EQUATION, INDETERMINATE. One containing two or more variables and, in general, satisfied by an infinite number of values for each of the unknowns. (See **diophantine equation.**)

EQUATION, LINEAR. (1) A **linear algebraic equation** has the form $a_1x_1 + a_2x_2 + \cdots + a_nx_n = a_0$, where the a_i are constants and the x_i are the variables. (2) A set of **simultaneous linear equations is**

$$\sum_{j=1}^{n} a_{ij}x_j = b_i; \quad i = 1, 2, \cdots, n$$

where a_{ij} and b_i are constants. (3) A linear **differential equation** is

$$A_0(x)y + A_1(x)y' + A_2(x)y'' + \cdots + A_n(x)y^{(n)} = f(x)$$

where the $A_i(x)$ are functions of the independent variable only and $y', y'', \cdots$ are the first, second, etc., derivatives. These equations are also **inhomogeneous.** If the right-hand side is zero in any case, the equation is still linear but **homogeneous.**

EQUATION OF CONTINUITY. In one form of the equation of continuity, the principle of the conservation of matter is stated in the following form: The rate of increase of the particles in an element of volume is equal to the net inward flow across the surfaces of the element. In mathematical terms

$$\frac{d\rho}{dt} + \mathrm{div}\,\mathbf{j} = 0$$

where ρ is the density of the medium and $\mathbf{j}$ is the mass **current density** vector. With proper changes in the meaning of ρ and $\mathbf{j}$, the equation expresses the conservation of other quantities, such as charge, energy, etc.

EQUATION OF MATHEMATICAL PHYSICS. One of the **partial differential equations** which were the principal object of study in classical mathematical physics. They are: (1) the **Laplace equation,**

$$\nabla^2\phi = 0$$

and its inhomogeneous analogue, the **Poisson equation;** (2) the equation of **wave motion,**

$$c^2\nabla^2\phi = \partial^2\phi/\partial t^2;$$

(3) the **diffusion equation,** which also applies to thermal conduction,

$$a^2\nabla^2\phi = \partial\phi/\partial t;$$

(4) the equation of **telegraphy,**

$$a\partial^2\phi/\partial t^2 + b\partial\phi/\partial t = \partial^2\phi/\partial x^2.$$

The parameters are observable quantities and t is the time. In modern theoretical physics, the differential equations of quantum mechanics, particularly the **Schrödinger wave equation,** must be included.

EQUATION OF MOTION. See **kinematics.**

EQUATION OF MOTION OF A RIGID BODY, GENERAL. See **kinematics; rigid body (general equation of motion).**

EQUATION OF STATE. A relationship which defines, or partly defines, the physical conditions of a homogeneous system by relating its pressure, temperature, volume or concentration, and the gas constant. Furthermore, all equations of state, except the simple $PV = RT$, contain additional constants or variables. (Also see **characteristic equation; equation of state, general; equation of state, thermodynamic; Keyes equation; Berthelot equation; Beattie and Bridgman equation; van der Waals equation; Dieterici equation;** and **Clausius equation.**)

EQUATION OF STATE, GENERAL. The most general form of the equation of state, relating the pressure, volume, and temperature of a gas, and the gas constant. It is of the form

$$PV = RT\left(1 + \frac{B}{V} + \frac{C}{V^2} + \frac{D}{V^3}\cdots\right)$$

in which P is the pressure, V the volume, T the absolute temperature, R the gas constant, and B, C, D, etc., are constants, dependent upon the temperature and called virial coefficients. The equation is sometimes referred to as the virial equation of state.

EQUATION(S) OF STATE, THERMODYNAMIC. See **thermodynamic equations of state.**

EQUATION, PARAMETRIC. A plane curve is usually described by a single equation in two variables representing **rectangular** or **polar coordinates.** Sometimes it is preferable to represent the curve by parametric equations expressing the coordinates separately in terms of a third variable, the **parameter.** Parametric equations of surfaces and of curves in space are also useful.

EQUATION, POLYNOMIAL. An equation of the form $P(x_1, x_2, \cdots, x_n) = 0$, where $P(x_i)$ is a **polynomial** in one or more variables. The case which occurs most frequently is the polynomial equation in one variable, $a_0x^n + a_1x^{n-1} + \cdots + a_n = 0$. For it, the fundamental theorem of algebra states that there

exists one and only one set of constants, x_1, x_2, $\cdots$, x_n, such that

$$(x - x_1)(x - x_2)(x - x_3) \cdots (x - x_n) = 0.$$

The constants are the **roots** of the polynomial equation. They may be real or complex, but they need not all be different. If $k \leq n$ roots are equal to each other, the root is said to be k-fold. The following relations hold for the roots:

$$x_1 + x_2 + \cdots + x_n = -a_1/a_0;$$

$$x_1x_2 + x_2x_3 + \cdots + x_{n-1}x_n = a_2/a_0;$$

$$x_1x_2x_3 + \cdots + x_{n-2}x_{n-1}x_n = -a_3/a_0; \quad \cdots;$$

$$x_1x_2x_3 \cdots x_n = (-1)^n a/a_0.$$

The roots of **linear, quadratic, cubic,** and **quartic** equations may be obtained in terms of algebraic expressions containing the coefficients but polynomials of degree higher than four cannot be solved in this way Approximate values of the roots of equations of any degree may be determined by graphical or numerical methods. For the latter procedures see **Horner's method, Newton's method, Graeffe's method, iteration method.** Properties of the roots can be found by **Descartes' rule** and **Sturm's theorem.**

EQUATION, QUADRATIC. An algebraic equation of the second degree in one or more variables. If there are two variables, the resulting curves are **conic sections** (see **quadratic equation in two variables**); if three variables, **quadric surfaces** are obtained.

EQUATION, QUARTIC. An algebraic equation of the fourth degree in one or more variables. Also called a **biquadratic equation.**

EQUATION SOLVER. A computing device, often of the **analog** type, which is designed to: (1) solve systems of linear simultaneous (nondifferential) equations, or (2) find the roots of polynomials, or both.

EQUATION, TRANSCENDENTAL. An equation which is not algebraic and containing one or more **transcendental functions.** Such an equation is generally designated by the name of the transcendental functions which it contains It cannot be solved by direct analytical methods in the usual case. Approximate roots may be found by the methods of **"Regula Falsi," Newton,** or **iteration.** Graphical methods are also possible, especially if only a few significant figures are wanted.

EQUATION, TRANSMUTATION. An equation for the change of one atom into another, which differs from it in nuclear charge, mass, or stability. Such changes occur in natural **radioactive processes,** but the general need for a systematic notation for expressing them came only with the investigation of **artificial radioactivity,** and the great number of changes discovered.

Two representative **transmutation** equations are

$${}_{13}Al^{27} + {}_0n^1 \rightarrow {}_{12}Mg^{27} + {}_1H^1$$

which shows the transmutation of aluminum atoms of mass number 27, by bombardment with neutrons, to magnesium atoms of mass number 27, with the emission of a proton, and

$${}_4Be^9 + \gamma \rightarrow {}_4Be^8 + {}_0n^1$$

which shows the transmutation of beryllium atoms of mass number 9, under gamma ray bombardment, to beryllium atoms of mass number 8, with the emission of a neutron.

The two reactions above may also be expressed in condensed form as:

$$Al^{27}\ (n; p)\ Mg^{27}$$

and

$$Be^9\ (\gamma; n)\ Be^8.$$

EQUILIBRIUM. A condition in which all the forces or tendencies present are exactly counterbalanced or neutralized by equal and opposite forces and tendencies. In a state of equilibrium, at least some of the quantities describing the system are independent of time.

EQUILIBRIUM, APPARENT. (False equilibrium.) A condition of apparent equilibrium in a system which is brought about by the interference of some factor (usually accidental) that prevents the system from proceeding to a true equilibrium.

EQUILIBRIUM, CONDITIONS OF MECHANICAL. See **equilibrium of forces on a rigid body.**

EQUILIBRIUM CONSTANT. A complex **phase** consisting of n components A_1, A_2 $\cdots$ A_n, reacting according to the equation

$$\nu_1A_1 + \nu_2A_2 + \cdots \nu_nA_n \rightleftharpoons 0$$

(products of the reaction have negative values of ν) will be in chemical equilibrium when

$$\nu_1\mu_1 + \nu_2\mu_2 + \cdots \nu_n\mu_n = 0$$

where μ_r is the **chemical potential** of the rth component. Writing

$$\mu_r = \mu_r^0 + RT \ln a_r$$

where μ_r^0 is standard **chemical potential,** and a, the **activity,** then

$$\sum_r \nu_r\mu_r^0 = -RT \sum_r \ln a_r^{\nu_r}.$$

The left-hand side is a constant depending only on the temperature and is written as $RT \ln K$, where K is the equilibrium constant, i.e.,

$$K = a_r^{-\nu_1}a_r^{-\nu_2} \cdots a_n^{-\nu_n}.$$

EQUILIBRIUM CONSTANT IN TERMS OF CONCENTRATIONS. From the general definition of **equilibrium constant,** it can be shown that for a chemical reaction in a dilute solution,

$$K = \left\{\left(\frac{M_0}{1000\rho_0}\right)^{\sum_n \nu_n} C_1^{\nu_1}C_2^{\nu_2} \cdots C_n^{\nu_n}\right\}^{-1}$$

where $C_1, C_2 \cdots C_n$ are the concentrations of the components in moles per liter, M_0 the molecular weight of the solvent, ρ_0 its density. In this case, since the initial factor in the expression is constant, an equilibrium function

$$K' = \{C_1^{\nu_1}C_2^{\nu_2} \cdots C_n^{\nu_n}\}^{-1}.$$

EQUILIBRIUM CONSTANT IN TERMS OF MOLE FRACTIONS. From the general definition of **equilibrium constant** it can be shown that for a mixture of ideal gases

$$K = \{x_1^{\nu_1}x_2^{\nu_2} \cdots x_n^{\nu_n}p^{\nu_1\nu_2 \cdots \nu_n}\}^{-1}$$

where $x_1, x_2 \cdots x_n$ are equilibrium values of the molar fractions, and p, the total pressure.

EQUILIBRIUM CONSTANT IN TERMS OF PARTIAL PRESSURES. From the general definition of **equilibrium constant** it can be shown that for a mixture of ideal gases,

$$K = \{p_1^{\nu_1}p_2^{\nu_2} \cdots p_n^{\nu_n}\}^{-1}$$

where $p_1, p_2 \cdots$ are the equilibrium partial pressures of the components.

EQUILIBRIUM DIAGRAM. A graphical representation, commonly plotted from temperature and composition, or pressure data, which shows the condition of equilibrium between various **phases** of a substance, or system of substances.

EQUILIBRIUM, HETEROGENEOUS. (Polyphase equilibrium.) Equilibrium between two or more phases, as between a solid and a gas, or a liquid and its saturated vapor. The system calcium oxide-calcium carbonate-carbon dioxide is an example of an heterogeneous equilibrium state.

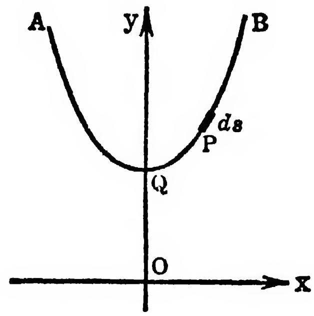
EQUILIBRIUM, HOMOGENEOUS. Equilibrium conditions in a system that constitutes a single phase, i.e., reactions in solution or among gases the products of which remain in the same phase as the reactants.

EQUILIBRIUM, ISOTHERMAL. An **equilibrium** reached by a system that remains at constant temperature during the entire process.

EQUILIBRIUM, METASTABLE. A definite **equilibrium** state which is not the most stable equilibrium under the given conditions. A metastable system will often undergo a spontaneous change upon addition of the stable phase, or frequently under the action of vibratory forces.

EQUILIBRIUM METHOD. See **freezing point depression measurement.**

EQUILIBRIUM OF A FLEXIBLE STRING. A string can be treated as possessing a continuous distribution of mass if it is essentially inextensible, i.e., if the tension varies little along its length. A string supported at its ends may be shown to assume a simple shape. Consider an element ds, measured along its length



The horizontal component of the tension on the element ds will be constant.

$$T_x = T\frac{dx}{ds} = \text{constant}$$

where T is the tension along the element ds. The vertical component of the tension on the element ds will be determined by the tension due to the amount of string between ds and the lowest point

$$T_y = T\frac{dy}{ds} = \rho g s$$

where s is the distance along the string from the lowest point to the element, ρ is the linear mass density, and g is the acceleration of gravity. The solution of these two differential equations indicates that the string hangs along a **catenary curve** with equation

$$y = \frac{h}{\rho g}\cosh\frac{\rho g x}{h}.$$

h is the perpendicular distance from the lowest point of the catenary to the x-axis.

EQUILIBRIUM OF A PARTICLE. A particle is said to be in equilibrium if the vector sum of all the forces acting through the particle is equal to zero. This condition can be expressed in component form by the equations $\Sigma F_x = 0$, $\Sigma F_y = 0$, $\Sigma F_z = 0$. Since a single particle does not possess the property of extension by definition, every force acting on the particle must act through the same point. Hence, the condition for equilibrium of a particle is identical with the first condition for equilibrium of rigid body as given under **equilibrium of forces.**

EQUILIBRIUM OF A PARTICLE ON A ROUGH SURFACE. The condition for equilibrium is the same as that for any particle. The force of friction must be included when determining the forces acting on the particle. (See **equilibrium of a particle; friction, coefficient of static.**)

EQUILIBRIUM OF A RIGID BODY. See **equilibrium of forces on a rigid body.**

EQUILIBRIUM OF A RIGID BODY WITH RESPECT TO ROTATION. A rigid body, initially at rest, is in rotational equilibrium if the algebraic sums of the **torques** about each of three mutually-perpendicular axes are zero. This is identical with the second condition for **equilibrium of forces on a rigid body.**

EQUILIBRIUM OF A RIGID BODY WITH RESPECT TO TRANSLATION. A rigid body is said to be in equilibrium with respect to translation if the vector sum of all the forces acting on the body is equal to zero. This condition is identical with the first condition for **equilibrium of forces on a rigid body,** and also with the single condition for equilibrium of a particle. The condition implies that the center of mass of the rigid body is not subject to any resultant force.

EQUILIBRIUM OF A SYSTEM OF CONNECTED PARTICLES. If a system of connected particles (e.g., joined by strings or rods, etc.) is acted on by external forces, the equilibrium of the whole can be studied by examining the equilibrium of each particle separately under the influence of *all* the forces which act on it. This is called the principle of separate equilibrium. It is useful in the study of flexible jointed cables.

EQUILIBRIUM OF FORCES ON A RIGID BODY. A state of balance between or among forces. The much used term equilibrium is here confined to its dynamical sense; such subjects as thermal equilibrium, radioactive equilibrium, etc., are treated in appropriate places elsewhere. Unless otherwise specified, the term refers to that set of conditions to which a system of forces must be adjusted in order that a free body acted upon by them will experience no acceleration. This is termed "static equilibrium," to distinguish it from the "kinetic equilibrium" with which **D'Alembert's principle** is concerned.

Two conditions are necessary for the equilibrium of a set of forces: (1) The vector sum of the forces must be zero; then if they are resolved into rectangular components, the algebraic sums of the X, the Y, and the Z components must separately reduce to zero, or symbolically, $\Sigma F_x = 0$, $\Sigma F_y = 0$, and $\Sigma F_z = 0$. (2) The algebraic sum of the torques of the forces about each of any three mutually perpendicular axes must be zero; the body then has no tendency to rotate about any axis. (See also **rigid body; torque; statics.**)

EQUILIBRIUM, ORDER OF. A method of classifying chemical equilibria. Equilibria of the first order embrace cases where only one component is present; equilibria of the second order embrace two-component systems and so on for higher orders.

EQUILIBRIUM, PHOTOCHEMICAL. A position of **equilibrium** reached in a reversible chemical change in which one or both of the

reactions are sensitive to light, and with the presence of the effective radiation postulated as one of the conditions under which the equilibrium is reached.

EQUILIBRIUM POINT. The external conditions (such as temperature or pressure) at which a system is in **equilibrium.**

EQUILIBRIUM, PRINCIPLE OF SEPARATE. The principle whereby the equilibrium of several particles can be studied by examining the equilibrium of a single particle in the group with respect to all the forces acting on it. (See **equilibrium of a particle.**)

EQUILIBRIUM, RADIOACTIVE. In a system containing two or more radioactive elements, in which each element (except the first) is formed by radioactive disintegration of the element preceding it in the series present, radioactive **equilibrium** is reached when the rate of formation of any element from its parent is equal to its own rate of disintegration. This statement does not apply to the terminal element of the series present, which is nonradioactive.

EQUILIBRIUM, STABLE. An equilibrium state of a system of one or more particles such that the **potential energy** of the system is a minimum. (Contrast **equilibrium, unstable.**)

EQUILIBRIUM, UNSTABLE. An equilibrium state of a system of one or more particles such that the **potential energy** of the system is a maximum. For example, consider a particle located on the top of a spherical surface in a gravitational field. The potential energy of the particle will be a maximum with respect to other values which it might possess at other points on the sphere. If the sphere were turned over and the particle placed inside the sphere at the lowest point, then the potential energy would be a minimum and the equilibrium would be stable.

EQUIPARTITION OF ENERGY. If a great number of perfectly elastic, rapidly moving particles are turned into an enclosure together and are allowed time to mingle, darting about and striking or otherwise encountering each other, the kinetic energy which they possess becomes distributed in accordance with the famous principle of equipartition of energy, or Maxwell-Boltzmann law, as enunciated by Boltzmann. Each particle has a number of **degrees of freedom,** determined by its character, and equal to the number of coordinates necessary to describe its position and orientation. (For the molecules of a diatomic gas, such as nitrogen, the effective number is 5; plus some others not ordinarily concerned with thermal energy.) The equipartition principle states that the average energy taken up by motions in each of the several degrees of freedom is the same, and is independent of the sizes and masses of the particles. (For a gas it is equal to ½ the product of the Boltzmann constant by the absolute temperature of the gas.) Thus when heat energy is imparted to a pure diatomic gas, ⅕ of it goes into each degree of molecular freedom which heat can affect. Three of these degrees of freedom are concerned with motions of translation, so that ⅗ of the energy takes this form. And indeed, when one calculates the change in translational energy due to raising the temperature of one gram of the gas one degree (see **kinetic theory**), it is found to be almost exactly ⅗ of the specific heat as measured at constant volume, which represents the total imparted energy. One of the strongest supports of the principle comes from quantitative observations on the **Brownian movement.** Many other examples occur in physics. The principle of equipartition of energy breaks down when at low temperature or under any other conditions in which the influence of the **quantum principle** becomes dominant.

EQUIPHASE SURFACE. (1) In a three-dimensional wave, $A(x,y,z)e^{i[\omega t-\Phi(x,y,z)]}$, the surfaces $\Phi(x,y,z)$ = constant are called **equiphase surfaces.**

(2) Thus, any surface in a **wave** over which the **field vectors** at the same instant are in phase or 180° out of phase.

EQUIPOTENTIAL CATHODE. See **cathode, unipotential.**

EQUIPOTENTIAL REGION. A field-free region. If the **potential** is uniform in a region,

$$\nabla\phi = 0,$$

hence there is no electric field. Conversely if

$$\mathbf{E} = -\nabla\phi = 0,$$

ϕ is independent of position.

EQUIPOTENTIAL SURFACE. A surface on which the **potential** is independent of posi-

tion. At each point of the surface, the **gradient** $\nabla\phi$ crosses perpendicularly, i.e., equipotential surfaces are **normal** to the lines of force.

EQUISIGNAL RADIO-RANGE BEACON. An aircraft-guidance **radio-beacon** which transmits two distinctive signals which may be received with equal strength only in certain sectors called equisignal sectors.

EQUISIGNAL SECTOR. The region in which the transmissions from an **equisignal radio-range beacon** may be received with equal intensities.

EQUIVALENCE PRINCIPLE. It is always possible at a point in space-time to transform to a (in general accelerated) coordinate system such that the effects of gravity will disappear over a differential region in the neighborhood of the point. As a particular case, if there are two observers, one uniformly accelerated with acceleration g and not in a gravitational field, the other not accelerated but held in a uniform gravitational field g, the results of mechanical and optical experiments performed by the two observers will be identical. (See **relativity theory, general.**)

EQUIVALENCE THEOREM. The field in a source-free region bounded by a surface could be produced by a distribution of electric and magnetic currents (**current-sheets**) on that surface that would be equivalent, for points inside the surface, to the actual external sources. (See **induction theorem.**)

EQUIVALENT CIRCUIT. An electrical circuit which is electrically equivalent to another circuit, or sometimes, to a mechanical device. Equivalent circuits of mechanical systems or electromechanical systems such as loud-**speakers** enable the designer to apply methods of circuit analysis, and often obtain a solution easily which would be very difficult if not impossible otherwise. The equivalent circuit method is used extensively in the analysis of communications circuits, particularly those involving vacuum **tubes.** The tube itself may be replaced, for instance, by a generator having a generated voltage equal the amplification factor of the tube times the applied grid voltage and an internal resistance equal the dynamic **plate resistance** of the tube. While this does not give the d-c solution of the tube circuit it does allow the circuit to be simplified for alternating currents and these are usually the ones of interest. Similarly, many other types of electrical circuits may be simplified in terms of equivalent circuits, sometimes giving all the necessary solutions, sometimes giving solutions for limited conditions, but, in most cases, greatly decreasing the labor involved in analyzing the circuit or equipment.

EQUIVALENT CONDUCTANCE. See **conductance, equivalent.**

EQUIVALENT CONSTANT POTENTIAL (X-RAYS). The constant potential which must be applied to an **x-ray tube** to produce radiation having an absorption curve in a given material closely similar to that of the beam under consideration.

EQUIVALENT DIODE. See **diode, equivalent.**

EQUIVALENT ELECTRONS. For an atom, electrons in the same **orbital** (whereby they have the same principal quantum number and the same azimuthal quantum number). For a molecule, electrons having the same quantum numbers, apart from spin, and the same **symmetry** g or u.

EQUIVALENT LOUDNESS LEVEL. See **loudness level.**

EQUIVALENT NETWORK. See **network, equivalent.**

EQUIVALENT NUCLEI. Sets of those nuclei in a molecule which can be transformed into one another by the symmetry operations permitted by the molecule (e.g., the three H atoms in CH_3-CCl_3 are equivalent).

EQUIVALENT NOISE PRESSURE. See **transducer equivalent noise pressure.**

EQUIVALENT POTENTIAL TEMPERATURE. See **potential temperature, equivalent.**

EQUIVALENT STOPPING POWER. See **stopping power.**

EQUIVALENT THICKNESS. The thickness, expressed in terms of the mass per unit area, of a foil which will just prevent the passage of α-particles of known range in air. The equivalent thickness in mg/cm^2 is equal

to the product of the range (in cm) and the density (in mg/cm³). (See **stopping power.**)

EQUIVOCATION. A measure of the average ambiguity of a received signal. It is the residual remaining uncertainty when the received signal has been interpreted.

ERASING HEAD. A device for obliterating any previous **recordings.** It may be used for preconditioning magnetic media for recording purposes.

ERBIUM. Rare earth metallic element. Symbol Er. Atomic number 68.

ERG. A unit of work or energy in the c gm s system of units, being the work done when a steady force of one dyne produces a displacement of one centimeter in the direction of the force.

ERGOMETER. See **power.**

ERGON. A **quantum** of **energy** ϵ, which is calculated for any given oscillator by multiplying the frequency of the oscillator by **Planck's constant.**

ERIOMETER. An apparatus for measuring small diameters, such as those of textile fibers, by observing the diameter of the **diffraction** pattern which they produce when viewed through the apparatus.

ERROR. The quantity which must be subtracted from an observed or calculated quantity to yield a closer approximation to the true value. The error is equal in magnitude and opposite in sign to the **correction.**

ERROR, ACCIDENTAL. In repeated observations of a quantity which is in principle constant, it is in general found that slightly different values are obtained. Errors of this type, which are beyond the control of the observer under the particular conditions of measurement, are known as accidental errors. The mean of the values obtained in the series of measurements is generally taken as the best estimate of the true value of the quantity, and the spread of the individual observations about this mean is used to estimate the **uncertainty** of this mean. Among the quantities used for this purpose are the **average deviation,** the **probable error,** and the **standard deviation.** (See also **error function** and **error, propagation of.**)

ERROR, ESTIMATED. The amount by which a measured or calculated quantity is believed likely to depart from the true value. (See **error, accidental.**)

ERROR FUNCTION. The **improper integral**

$$\text{erf}\,(t) = \frac{2}{\sqrt{\pi}} \int_0^t e^{-y^2} dy.$$

When the results of a series of measurements are described about an average by a Gaussian curve, erf (ha) is the probability that the error of a single measurement lies between $\pm a$, where h is the precision index. The integral cannot be evaluated in closed form but must be expanded in a **power series** and integrated term by term. Values of the integral, as functions of t, have been tabulated (See also **Fresnel integral.**)

ERROR, INSTRUMENTAL. Any error in measurement which results from the properties of the instruments used in the measurement. Instrumental errors may be divided into scale errors, which result from improper calibration of the instrument, and reproducibility errors, which result from the failure of the instrument to give the same indication whenever it is subject to the same input signal The latter type may be treated as accidental errors, the former may not.

ERROR, PERSONAL. Any error which results from the tendency of an observer to misread an instrument, e g., to read consistently high or low. Personal errors are not distributed in the same manner as accidental errors, and their magnitudes may be estimated only by the comparison of observations made by different observers.

ERROR, PROBABLE. See **probable error.**

ERROR, PROPAGATION OF. When a quantity is calculated as a function of one or more measured quantities, instead of being measured directly, it is often necessary to estimate the uncertainty in the calculated quantity which results from the estimated errors of the measured quantities. Two distinct cases arise.

(1) If the quantity z is a function of a single measured quantity x, i.e , $z = z(x)$,

$$\delta z = \frac{\partial z}{\partial x}\,\delta x,$$

where δx is the uncertainty of x and δz is the corresponding uncertainty of z.

(2) If the quantity z is a function of two or more measured quantities, e.g., if $z = z(x,y)$,

$$\delta z = \left[\left(\frac{\partial z}{\partial x}\right)^2 (\delta x)^2 + \left(\frac{\partial z}{\partial y}\right)^2 (\delta y)^2\right]^{\frac{1}{2}}.$$

These rules apply only if the errors are symmetrically distributed about the mean, i.e., if positive and negative errors are equally probable.

ERROR, SCALE. Any error in measurement which results from a miscalibration of an instrument, e.g., the use of a linear scale with an instrument which departs slightly from linearity of response to the input signal.

ESCLANGON EFFECT. The **deviation** of a ray of reflected light due to motion of the mirror in a direction oblique to its surface

ESR. Abbreviation for **effective signal radiated.**

ESU. An abbreviation for any unit in the **esu system of units.** Now obsolescent, having been replaced by the prefix stat- attached to the name of a unit in the practical system. E.g., statampere, statmaxwell.

ESU SYSTEM OF UNITS. A system of units based on the choice of the **permittivity** of empty space as unity and dimensionless. The units are usually denoted by the prefix stat- attached to the name of a unit in the practical system. E.g., statvolt, statoersted.

ETA. (1) Efficiency(η). (2) Coefficient of viscosity (η). (3) Electric susceptibility (η). (4) Transverse acoustic displacement (η). (5) Displacement component of sound-bearing particle (η). (6) Electronic state of molecule having Λ-value of 5 (H).

ETALON. See **Fabry and Perot etalon.**

ETHER HYPOTHESIS. Postulate, widely held in the nineteenth century, that all space is filled with a fluid which is transparent, undispersive, incompressible, continuous and without viscosity. This fluid was supposed to act as a medium for the propagation of light analogous to the manner in which sound is propagated through matter Later it was regarded as a seat of all electromagnetic energy and attempts were made to describe matter in terms of vortices in this fluid.

The hypothesis appeared to find experimental verification in the result due to Fresnel that the velocity of light relative to the ether on passing through a medium of refractive index n, velocity v (in the same direction) is

$$\frac{c}{n} + \left(1 - \frac{1}{n^2}\right)v,$$

and in the **Airy experiment** on aberration. This theory required, however, that matter moving through the ether should modify the velocity of the ether and that because of **dispersion** the relative velocity of medium and ether would be different for different wavelengths, thus requiring a different ether for each wavelength. The chief difficulty which the hypothesis encountered, however, arose from the juxtaposition of the two well-established theories of non-relativistic Newtonian dynamics and of Maxwell's electromagnetism. Under a **Galilean transformation** the equations of the former are invariant while those of the latter are not. Thus at any point there should be one special coordinate system, at rest relative to the local ether, relative to which Maxwell's equations assume their usual form. Motion relative to this ether should therefore be detectable, although various attempts to observe it (e.g., the **Michelson-Morley experiment**) had been unsuccessful. To avoid this difficulty the **Lorentz-Fitzgerald contraction hypothesis** was advanced, but the ether theory was finally abandoned when the Galilean transformation and the dynamics of Newton received their modifications in the Einstein **special relativity theory.**

ETTINGSHAUSEN EFFECT. This phenomenon, discovered in 1887, is analogous to the **Hall effect** and appears to be closely related to it. If a strip of metal in which an electric current flows longitudinally is placed in a magnetic field with the plane of the strip perpendicular to the direction of the field, it is found that corresponding points on opposite edges come to different temperatures. If, to one looking along the strip in the direction of the current, and with the magnetic field downward, the decrease of temperature is toward the right, the effect is positive. This is the case with bismuth, in which the phenomenon was first observed by Ettingshausen. The same is true of antimony, nickel, and cobalt; but in iron the effect is negative. (See also **Nernst** and **Righi-Leduc effects.**)

EUCLIDEAN SPACE. Riemannian space in which it is possible to introduce a coordinate system with respect to which $g_{\mu\nu} = \delta_{\mu\nu}$ at every point ($g_{\mu\nu}$ is the **metric,** $\delta_{\mu\nu}$ is the **Kronecker delta**).

EUCOLLOID. A **colloid** composed of relatively large particles, i.e., exceeding 0.25 micron in length.

EUDIOMETER. A graduated tube closed at one end in one form of which two platinum wires are sealed so that a spark may be passed through the contents of the tube. Used to measure the volume changes in the combustion of gases.

EULER ANGLE. One of three **parameters** describing the orientation of a rigid body relative to a **Cartesian coordinate system** (x,y,z) fixed in space. Suppose another coordinate system (x',y',z') is fixed in the body. Then the two systems may be made coincident by three successive rotations, applied in the appropriate order, and the three angles of rotation are the **Euler angles.** The order of performing the rotations and the symbols for the angles have been given in different ways by various authors so that some confusion exists in the literature of mechanics, where these parameters are most frequently used, as to the definition of the angles. (See also **Euler-Rodrigues parameter, Cayley-Klein parameter.**)

EULER CRITERION. See **Euler reciprocity relation.**

EULER EQUATION. The condition that the integral

$$\int_{x_1}^{x_2} I(x,y,y')dx$$

have a stationary value is

$$\frac{\partial I}{\partial y} - \frac{d}{dx}\frac{\partial I}{\partial y'} = 0.$$

A solution $y = f(x)$ satisfying this equation, if it exists, is an **extremal** and is a maximizing or a minimizing curve. (See **calculus of variations.**)

EULER EQUATIONS OF MOTION. For a rigid body with one point fixed and coordinates fixed in the body and coinciding with the principal axes, the equations of motion of the body can be written as

$$I_{xx}\dot{\omega}_x + (I_{zz} - I_{yy})\omega_y\omega_z = L_x$$
$$I_{yy}\dot{\omega}_y + (I_{xx} - I_{zz})\omega_z\omega_x = L_y$$
$$I_{zz}\dot{\omega}_z + (I_{yy} - I_{xx})\omega_x\omega_y = L_z$$

where I_{xx}, I_{yy} and I_{zz} are the moments of inertia about the principal axes, L_x, L_y and L_z are the components of torque about the principal axes, ω_x, ω_y and ω_z are the components of the angular velocity about the principal axes. (See **moments of inertia; rotational motion.**)

EULER FORMULA (COLUMNS). A formula which gives the maximum axial load that a long, slender ideal column can carry without buckling. An ideal column is one which is perfectly straight, homogeneous and free from initial stress. This maximum load, sometimes called the critical load, causes the column to be in a state of unstable equilibrium, that is, any increase in the loads or the introduction of the slightest lateral force will cause the column to fail by buckling. The Euler formula for columns is given below.

$$P = \frac{K\pi^2 EI}{l^2}$$

in which P = maximum or critical load, E = modulus of elasticity, I = moment of inertia of cross-sectional area, l = unsupported length of column, K = a constant whose value depends upon the conditions of end support of the column. For both ends free to turn $K = 1$; for both ends fixed, $K = 4$; for one end free to turn and the other end fixed $K = 2$ approximately, and for one end fixed and the other end free to move laterally $K = \frac{1}{4}$.

EULER INTEGRAL. See **beta function** and **gamma function.**

EULER-MACLAURIN FORMULA. An equation for evaluating a **definite integral.** If $f(x)$ is known explicitly and its derivatives are finite at both limits of the integral, or if the derivatives may be determined numerically, the formula may be used. Its form is

$$\int_a^b f(x)dx = h\left[\frac{y_0}{2} + y_1 + y_2 + \cdots + \frac{y_n}{2}\right]$$
$$- \sum_{\text{odd } k} \frac{h^{k+1}}{(k+1)!} B_{k+1}[y_n^{(k)} - y_0^{(k)}]$$

where y_0 and y_n are values of $f(x)$ at $x = a$ and $x = b$, respectively; y_1, y_2, $\cdots$ are inter-

mediate values at equally spaced intervals h of the independent variable; B_k are the **Bernoulli numbers**; $y_n^{(k)}$ and $y_0^{(k)}$ are the k-th derivatives at $x = b$ and $x = a$, respectively. The formula may also be used to evaluate the finite sum indicated by the first term on the right-hand side of the equation, provided the integration can be performed.

EULER-MASCHERONI CONSTANT. See **gamma function.**

EULER METHOD FOR NUMERICAL SOLUTION OF A DIFFERENTIAL EQUATION. An **iteration method** for solving a **differential equation,** $y' = f(x,y)$, where initial values of x_0, y_0, y_0' are known. If the interval between successive values of the independent variable is small enough to write $\Delta x = h$, then an approximate solution of the differential equation at $x_1 = x_0 + h$ is ${}^1y_1 = y_0 + hy'_0$. An approximation to y' at x_1 is $y'_1 = f(x,{}^1y_1)$, which gives an improved value of y_1, ${}^2y_1 = y_0 + (h/2)(y'_1 + y'_0)$. The process is then repeated. The method just described is actually a modification of that proposed by Euler. However, both it and the original Euler method are slow in converging and give results of low accuracy. While they are suitable for starting the solution of a differential equation, more accurate methods are preferred for continuing the solution.

EULER RECIPROCITY RELATION. If Z is a single-valued function of the variables x and y, the total or exact differential dZ may be written

$$dZ = Xdx + Ydy,$$

where X and Y are also functions of x and y. Then it can be shown that

$$\left(\frac{\partial X}{\partial y}\right)_x = \left(\frac{\partial Y}{\partial x}\right)_y.$$

This is known as the Euler criterion, or reciprocity relation. It is useful for deriving thermodynamic relationships, e.g., the Maxwell relations.

EULER-RODRIGUES PARAMETER. One of four **parameters** used to describe the orientation of a rigid body. They are functions of three **direction cosines** and they form the components of a **quaternion.** (See also **Euler angle, Cayley-Klein parameter.**)

EULER THEOREM ON HOMOGENEOUS FUNCTIONS. See **function, homogeneous.**

EULERIAN ANGLE. See **Euler angle.**

EULERIAN COLUMN. See **Euler formula (columns).**

EULERIAN METHOD OF ANALYSIS OF FLUID MOTION. The method of analysis of fluid motion which considers the distribution of fluid velocities in space as a function of time. In general, the method is better suited to the analysis of fluid motion than the **Lagrangian method.**

EUROPIUM. Rare earth metallic element. Symbol Eu. Atomic number 63.

EUTECTIC. A minimum temperature and corresponding composition (in other words, a minimum point upon a temperature-composition diagram) at which a liquid consisting of two or more components is in equilibrium with its components in the solid state, or with a particular group of solid substances derived from its components, and which may include one or more elements, compounds or solid solutions. Material of this composition is often called an "eutectic"; and the temperature of this point is sometimes called the eutectic temperature. It represents the lowest melting point of the system This temperature is constant, and is analogous in many respects to constant boiling mixtures of liquids.

EUTECTIC HALT. An **arrest point** in the **equilibrium diagram** of two or more components, due to the appearance of the **eutectic** mixture.

EUTECTOID. A point that has the same properties as a **eutectic,** but occurs in a completely solid region.

EV. Abbreviation for **electron volt.**

EVAPORATION. The conversion of a substance from the liquid state into the vapor state.

EVAPORATION OF ELECTRONS. The cooling at a surface due to the loss of electrons from that surface.

EVAPORIMETER. An instrument for measuring the rate of evaporation of water into the atmosphere.

EVASION COEFFICIENT. A factor which expresses the number of milliliters of a gas under standard conditions evolved per minute from one square centimeter of the surface of its solution in a liquid.

EVEN-EVEN NUCLEI. Nuclei which contain an even number of **protons** and an even number of **neutrons.**

EVEN-ODD NUCLEI. Nuclei which contain an even number of **protons** and an odd number of **neutrons.**

EVEN TERM OF ATOM. A term for which Σl_i, summed over all the electrons of the atom, is even. The eigenfunctions for even terms remain unchanged for a reflection of all particles at the origin.

EVENT, ABSOLUTE FUTURE OF. See **absolute future of an event.**

EVENT, ABSOLUTE PAST OF. See **absolute past of an event.**

EVJEN METHOD. A method for the evaluation of **lattice sums** in which charges of opposite signs are taken together in neutral groups, so that the contribution of each group is small and the sum converges rapidly

EVOLUTION. The operation of extracting a **root** of a number It is the process inverse to **involution.**

EWALD METHOD. A technique for evaluating **lattice sums** in which the series are made rapidly convergent by certain mathematical devices.

EWALD-KORNFELD METHOD. An extension of the **Ewald method** for **lattice sums** to dipole arrays.

EWING THEORY OF FERROMAGNETISM. Ewing was one of the first to attempt to explain **ferromagnetic** phenomena in terms of the forces between atoms. He assumed that each atom was a permanent magnet free to turn in any direction about its center, and assumed the orientations to depend only on magnetic forces: applied fields and mutual interactions. His theory leads to good qualitative results, such as the **hysteresis curve,** but quantitatively is unsatisfactory by several orders of magnitude.

EXALTATION. The positive difference between the observed and the calculated values of the **molar refractivity** of a substance. (See **optical exaltation.**)

EXALTED-CARRIER RECEPTION. An **amplitude-modulation** receiver system which maintains the carrier level at a high value at all times to decrease selective fading and the resulting detector distortion One way in which this may be achieved is by the synchronization of a local **oscillator** by the carrier for the purpose of obtaining a constant-amplitude voltage of carrier frequency which may be used to drive the detector.

EXCESS CONDUCTION. In a **semiconductor,** conduction by **excess electrons,** for example, by electrons introduced by **donor impurities** and promoted to the **conduction band.**

EXCESS ELECTRON. In a **semiconductor,** an electron which represents an excess over and above those required to complete the bond structure in the **neighborhood.**

EXCESS PRESSURE OF SOUND. The instantaneous pressure (see **pressure, instantaneous**) at a point in a sound wave minus the hydrostatic pressure. (See **pressure, hydrostatic.**)

EXCESS 3 CODE. A code for numerical data in which each decimal digit d is represented by the binary number $(d + 3)$.

EXCHANGE DEGENERACY. An exchange process which does not entail a change in value or configuration. For example, by the Heitler-London theory, the essential reason for the strong attraction (or repulsion), of the two H-atoms in the H_2 molecule is the exchange degeneracy, i.e., the fact that for very large internuclear distance, by exchange of the two electrons of the two atoms a configuration results that is indistinguishable from the original configuration Therefore, as they approach, an interaction between them **arises** which may be treated mathematically as electron exchange.

EXCHANGE ENERGY. A specifically quantum-mechanical effect (see **quantum mechanics**) which has no classical analogue. It is due to the interaction between two systems that arises, or could arise, from the continuous exchange of a particle between them. Suppose, for example, that two electrons are in

states that allow them to come close together. Then, because they are indistinguishable particles, one could not tell the difference if they exchanged states. That is, one must combine with the original description (i.e., **wave-function**) a function in which the electrons have actually changed places. It can easily be shown that two such combined states are possible—the symmetric and antisymmetric combinations—and that in each of these the energy is significantly different from that of the original state. The magnitude and sign of the effect depends upon the **exchange integral.** Exchange energy is the origin of **covalent bonding,** of **ferromagnetism** and **antiferromagnetism,** probably of **nuclear forces** (where exchange energy could arise by exchange of π-mesons between nucleons, giving rise to an effective potential which involves an operator which exchanges the spins, isotopic spins and/or positions of the particles) and of numerous other physical phenomena.

EXCHANGE INTEGRAL. An expression of the form

$$\iint \psi_1{}^*(\mathbf{r}_a)\psi_2{}^*(\mathbf{r}_b)\frac{e^2}{|\mathbf{r}_a - \mathbf{r}_b|}\psi_1(\mathbf{r}_b)\psi_2(\mathbf{r}_a)d\mathbf{r}_a d\mathbf{r}_b$$

where ψ_1, ψ_2 are electronic wave functions. It can be thought of as the Coulomb interaction between the state in which electron a, at $\mathbf{r}_a$, has wave function ψ_1 and electron b has wave function ψ_2, and the state in which the electrons have interchanged places. (See **exchange energy.**)

EXCHANGES, PREVOST LAW OF. See **Prevost law of exchanges.**

EXCITATION. (1) Addition of energy to a system, whereby it is transferred from its ground state to a state of higher energy, called an excited state. (2) The field excitation of dynamo machines, meaning the current or voltage of the field circuit. (3) In electron-tube circuits, the input signal of any stage is commonly called the excitation. Thus in a radio receiver, the signal picked up by the antenna supplies the excitation for the first stage, the output of the first supplies the excitation for the next, and so on

EXCITATION ANODE. See description under **excitron.**

EXCITATION BY ELECTRONS, PROBABILITY OF. The number of excited atoms per unit **electron current** per unit path length per unit pressure at 0°C.

EXCITATION, CUMULATIVE. See **cumulative excitation.**

EXCITATION CURVE. In **nuclear physics,** a graphical relationship between the energy of the incident particles or photons, and the relative yield of a specified **nuclear reaction.**

EXCITATION CURVE, THIN TARGET. A nuclear **excitation curve** in which the ordinates are proportional to the **cross sections** for the specified nuclear reaction.

EXCITATION CURVE, THICK TARGET. A nuclear **excitation curve** for an infinitely-thick **target.**

EXCITATION DRIVE. A **signal voltage** applied to the control electrode of an electron tube.

EXCITATION ENERGY. The energy necessary to change a system from its **ground state** to an **excited state.** Of course, for each excited state there is associated a corresponding excitation energy.

EXCITATION FUNCTION, ATOMIC. The **cross section** for the **excitation** of an atom to a particular excited state expressed as a function of the incident electrons.

EXCITATION FUNCTION, NUCLEAR. The **cross section** for a particular **nuclear reaction** expressed as a function of the energy of the incident particle or photon. The term excitation function is sometimes used also as a synonym for **excitation curve.**

EXCITATION PURITY (PURITY). The ratio of the distance from the reference point to the point representing the sample, to the distance along the same straight line from the reference point to the **spectrum locus** or to the purple boundary, both distances being measured (in the same direction from the reference point) on the CIE **chromaticity diagram.** The reference point is the point in the the chromaticity diagram which represents the reference standard light mentioned in the definition of **dominant wavelength.**

EXCITATION, SHOCK. The type of **excitation** supplied by a voltage or current varia-

tion of relatively short duration. The term is also used to indicate the initiation of motion in a mechanical system by an **impulse** of short duration.

EXCITED. As applied to a molecule, atom or nucleus, the term excited means having a higher energy than in the **ground state.**

EXCITED FIELD LOUDSPEAKER. See **loudspeaker, excited field.**

EXCITER. (1) In antenna terminology, the portion of a transmitting array (see **array, transmitting**), of the type which includes a **reflector,** which is directly connected with the source of power. (2) In transmitters, the **oscillator** which supplies the carrier or sub-carrier frequency voltage to drive the stages which ultimately lead to the final power output stage In FM systems this unit includes all the frequency generating, modulating and frequency multiplying circuits of the transmitter (3) In photoelectric reproduction of film, the lamp which supplies a light source of constant amplitude (4) A generator used to supply the field currents of a larger **direct current generator** or of an **alternator.**

EXCITING CURRENT. Synonym for **magnetizing current.**

EXCITING INTERVAL. In **magnetic amplifier** terminology, the portion of the a-c supply cycle in which the supply voltage is absorbed by the **gate winding.** The magnitude of this interval varies inversely with the magnitude of average **gate current.**

EXCITING REGION. The region in the control characteristic of a **magnetic amplifier** where the **gate current** is determined predominantly by the **magnetizing current** rather than the **control current.**

EXCITON. A combination of an electron and a **hole** in a **semiconductor** or insulator in an excited state. The hole behaves as a positive charge, and it is supposed that the electron is attracted to it to form a state akin to that of a hydrogen atom. The probability of the electron falling into the hole is limited by the difficulty of losing the excess energy, so that the exciton may have a relatively long life. The existence of these states may be inferred from the absorption of light associated with their excitation. (Cf **positronium.**) Alternatively, an exciton may be thought of as an excited state of an atom or ion, the excitation wandering from one cell of the lattice to another.

EXCITRON. A steel-tank, single-anode, mercury-pool cathode-rectifier which employs a solenoid-operated mercury jet to initiate the arc. Energization of the solenoid throws a jet of mercury from the pool upwards to the **excitation electrode.** When the mercury falls back, an arc is formed and the cathode spot is kept alive by an auxiliary d-c power source supplying the excitation anode The **grid** may then be used to determine the time of firing of the main anode.

EXCLUSION PRINCIPLE. See **Pauli exclusion principle.**

EXIT PUPIL. The image of the **aperture stop** as viewed from the image.

EXIT SLIT. A narrow opening in an opaque screen, when a **spectrum** is produced upon the screen, by a spectrometer, the slit passes only a small portion of the spectrum, which is then focussed onto a detector.

EXOERGIC. The same as **exothermic,** i e, giving forth heat or energy. (See **disintegration energy, nuclear.**)

EXOSMOSIS. An **osmotic** process by which a diffusible substance passes from the inner or closed, to the outer parts of a system, as in the loss of substances from a portion of a plant root to water in the surrounding soil.

EXOTHERMIC CHANGE. A physical or chemical change which proceeds with the development of heat.

EXPANDER. The part of the communication circuit designed to expand the volume range back to the original value as it is normally compressed for transmission

EXPANDING UNIVERSE. Non-static isotropic homogeneous model of the universe describing the mutual recession of nebulae and not in disagreement with the observed **density of matter.** Based on the **Einstein law of gravitation** including the **cosmological constant.**

EXPANSION. Commonly a process in which a constant mass of a substance undergoes an increase in size (length, width, area or volume). In thermal expansion this is brought

about by raising the temperature of the substance.

Each molecule of a body of matter in any state appears to monopolize a certain amount of space which, while it cannot be accurately called the volume of the molecule, does represent the contribution of that molecule to the volume of the whole body. The molecules are in a state of agitation; and it is to be expected that the space which any molecule monopolizes, or keeps clear for itself, will be larger, the greater the amplitude of its oscillations. Here is the fundamental reason for the expansion of bodies with rise of temperature. (See **heat.**)

The rate of expansion of a substance with temperature has been expressed by several different "expansion coefficients." The one now usually employed, as regards change of volume, may be defined as the rate of change of the volume of a body of the substance with respect to temperature, divided by its volume at a specified reference temperature:

$$\alpha_v = \frac{dv}{dt}/v_0. \tag{1}$$

Thus for iron at ordinary temperatures, α_v is about 0.000036 per degree centigrade. While not strictly constant, it is nearly enough so for ordinary purposes. By integration of (1) the volume at any temperature t is

$$v = v_0(1 + \alpha_v t). \tag{2}$$

These statements apply alike to solids, liquids, and gases. The fact that the coefficient α_v is nearly the same for all gases is expressed by the **Charles law.**

For solids one may also define a linear expansion coefficient, relating to the change in any one dimension l, thus:

$$\alpha_l = \frac{dl}{dt}/l_0, \tag{3}$$

from which the value of that dimension at any temperature t is

$$l = l_0(1 + \alpha_l t). \tag{4}$$

Since for an isotropic solid the volume at a given temperature is proportional to the cube of any dimension, it is easy to show that

$$\alpha_v = 3\left(\frac{l}{l_0}\right)^2 \alpha_l. \tag{5}$$

But for moderate temperatures l and l_0 are nearly equal, hence, practically, the volume coefficient is three times the linear. Thus the linear coefficient for iron is about 0.000012 per degree centigrade.

If from the known thermal capacity of a solid one can deduct the calculated energy corresponding to change of thermal agitation in all the atomic degrees of freedom, and also the energy expended in expansion against the external pressure, the remainder may be taken as representing the work of expansion against cohesion, and hence used as a means of calculating the "internal pressure" arising therefrom (See **adhesion and cohesion.**)

EXPANSION, ADIABATIC. An expansion of a substance or system of substances without gain or loss of heat by the substance or system

EXPANSION COEFFICIENT. See **expansion.**

EXPANSION OF SOLIDS, MEASUREMENT OF LINEAR. The various methods for determining the coefficient of linear expansion depend mostly on comparison of the change in length of the sample under investigation with a standard substance. If the sample is available in rod form, a simple comparator method can be used in which the change of length is measured against a rod or tube of the standard substance. The **Fizeau method** uses a sample in form of a disc with plane-parallel surfaces The upper surface is opposed by a glass plate which, close to the sample, rests on supports of the standard substance. The differential expansion is then observed through the movement of fringes, owing to the variation of the air-gap between sample and glass plate Essentially the same arrangement is used in an electrical method in which the top surface of the sample and the bottom surface of the glass plate are metal-coated to form a condenser. By making this variable condenser part of a resonant circuit the differential expansion can be measured with great accuracy

EXPERIMENT. An operation conducted for the purpose of determining some unknown fact or of obtaining knowledge concerning a general principle or truth.

EXPLOSION METHOD FOR SPECIFIC HEAT AT CONSTANT VOLUME. The gas under investigation is enclosed with a known

amount of explosive mixture into a bomb which is closed by a corrugated steel membrane, acting as manometer. The maximum temperature reached on ignition is deduced from the adiabatic pressure change. If Q is the heat of reaction, t_1 the initial and t_2 the final temperature, $Q = (t_2 - t_1)(W_1 + W_2)$, where W_1 is the heat capacity of the gas and W_2 that of the combustion products.

EXPONENT. The **power** to which an algebraic expression is raised. It can be positive or negative, integral or fractional. Same as **index.** (See **power** and **indicial equation.**)

An **exponential function** is **transcendental,** an example being $y = ab^x$, where a, b are constants and x is the independent variable.

EXPONENTIAL ABSORPTION. See **absorption, exponential.**

EXPONENTIAL CONNECTOR. An acoustic connecting tube whose cross-sectional area increases exponentially with the distance from one end. It is used to increase transmission between tubes of different cross-section On the basis of horn theory, the power transmission ratio P_r for an exponential connector of length l and cross-sectional area $S = S_0 \exp mx$ is given by

$$P_r = \frac{1}{1 + \frac{m^2}{x(k^2 - m^2/x)} \sin^2 (l\sqrt{k^2 - m^2/x})},$$

where $k = 2\pi/\lambda$ (λ = wavelength).

EXPONENTIAL DECAY. See **decay, exponential.**

EXPONENTIAL HORN. See **horn, exponential.**

EXPONENTIAL LINE. See **transmission line, exponential.**

EXPONENTIAL PILE. An assembly of fissionable material and **moderator** which contains too little fissionable material to sustain a **chain reaction.** When used with an extraneous source of neutrons, it provides information about the material **buckling** from measurements of the steady-state thermal neutron flux distribution throughout the assembly.

EXPONENTIAL WELL. See **potential, nuclear.**

EXPOSURE, ACUTE. Radiation exposure of short duration.

EXPOSURE - DENSITY RELATIONSHIP. The response of a sensitive material, as shown by the relationship between density and exposure, is usually represented by a curve in which density is plotted against the *logarithm* of the exposure. This curve is known as (1) the *D log E curve;* (2) the *H & D curve,* after Hurter & Driffield, two English investigators who were the first to plot such curves; and (3) as the *characteristic curve* since it indicates the principal characteristics of a sensitive material insofar as the relationship between exposure, development and density is concerned.

EXPOSURE METER. An instrument used in measuring light for the purpose of determining the proper photographic exposure. The measurement may be made by observing the output of a photocell which transforms light into an electric current or in a more simple type by visually comparing the radiation with a step gray scale. Some exposure meters are designed to measure the light reaching the subject, while others measure the light reflected by the subject. Most exposure meters include some sort of computing system for translating the measurement into the best **exposure time** and **f-number** to be used with film of a given speed.

EXPOSURE, PHOTOGRAPHIC. The product of **illuminance** I and time t of exposure. This definition assumes that the reciprocity law holds. Sometimes the exposure is taken as It^p, where p is a constant of the particular photographic emulsion and has a magnitude approximately equal to unity.

EXPOSURE TIME. The interval during which the receiver is irradiated. It is important to distinguish this term from exposure.

EXSECANT. If θ is an angle, exsecant θ = exsec θ = sec $\theta - 1$.

EXTENDED CUTOFF TUBE. A **remote-cutoff tube.**

EXTENSIVE SHOWER. See **shower, extensive.**

EXTERNAL FEEDBACK. Synonym for extrinsic feedback. (See **feedback, extrinsic.**)

EXTERNAL TERMINATION (OF THE *j*TH TERMINAL OF AN *n*-TERMINAL NETWORK). That passive or active two-terminal network which is attached externally between the *j*th terminal and the reference point.

EXTINCTION COEFFICIENT. See the **Beer law** and the **Bouguer law.**

EXTINCTION PHOTOMETER. A **photometer** in which the **luminous intensity** of a source of light is judged by the thickness of a given absorbing material necessary to render it just invisible.

EXTINCTION POTENTIAL. The lowest anode voltage which will cause a self-sustained discharge in a **gas-discharge tube.**

EXTRACT INSTRUCTION. In a digital computer, the instruction to form a new word by juxtaposing selected segments of given words.

EXTRAORDINARY GLOW. See **abnormal glow.**

EXTRAORDINARY INDEX. The **index of refraction** for the extraordinary ray in a **double refracting** crystal measured perpendicular to the optic axis (in which direction its value differs most from the index for the ordinary component).

EXTRAORDINARY RAY. If an unpolarized ray of light strikes the surface of a calcite or other **double-refracting** crystal normally, it will be divided into two transmitted rays. One ray, the ordinary, will not be bent, while the other ray, the extraordinary, will be bent on entering the crystal. Rotation of the crystal about the entrant ray causes the extraordinary ray to rotate about the ordinary ray. The extraordinary ray is a doubly-refracting crystal has its electric vector in the principal plane

EXTRAORDINARY-WAVE COMPONENT. The magneto-ionic wave component in which the **electric vector** rotates in the opposite sense to that for the **ordinary-wave component.**

EXTRAPOLATED RANGE. See **range.**

EXTRAPOLATION. Any process by which the value of a function is estimated for a value of the independent variable outside of the range in which the function has been determined.

EXTREMAL. See **calculus of variations and maximum.**

EXTREME PATH. See **Fermat principle.**

EXTREME RELATIVISTIC LIMIT. Limit to which a formula describing the behavior of a particle tends when the energy of the particle is large compared with its **rest energy.**

EXTRINSIC PROPERTIES (OF A SEMICONDUCTOR). The properties of a **semiconductor** as modified by **impurities** or **imperfections** within the crystal.

EYE LENS. See discussion of **field lens.**

EYE OF STORM. At the center of a **hurricane** there is usually a very small area in which winds are light and the sky nearly clear. This is known as the eye of the storm. A similar "eye of the storm" sometimes exists in temperate-zone **cyclones.**

EYEPIECE. The lens, or system of lenses, which is closest to the eye in an optical instrument such as a **telescope** or a **microscope** is known as the eyepiece or ocular. The eyepiece is usually a magnifying device used for the purpose of detailed examination of the real image formed by the objective of the instrument. It is usually designed to act as a collimator to the light from the objective so that the light from each point of the image formed by the objective emerges in parallel or nearly parallel rays.

EYEPIECE, CODDINGTON. See **Coddington eyepiece.**

EYEPIECE, HUYGENS. An **ocular** consisting of two thin lenses of the same sort of glass, and separated a distance equal to one half the sum of their **focal lengths.** This ocular is free from **chromatic aberration** with respect to focal length. It is not good for use with cross-hair **lines.**

EYEPIECE, KELLNER. See **Kellner eyepiece.**

EYEPIECE MICROMETER (MEASURING EYEPIECE). A finely-divided scale placed in the **focal plane** of the **eyepiece** of a microscope for the purpose of measuring the dimensions of objects viewed with the instrument. Sometimes a removable **cross-hair line** is provided, and its position is adjusted **by a micrometer** screw.

EYEPIECE, NEGATIVE. An **eyepiece** that is placed inside the principal focus of the **objective,** such as the Huygens type.

EYEPIECE, POSITIVE. An **eyepiece** which is essentially a simple magnifier focussed upon a real image from the **objective,** such as the Ramsden eyepiece.

EYEPIECE, RAMSDEN. The Ramsden eyepiece or magnifier commonly used in instruments with cross-hairs consists of a combination of two converging **lenses** of equal **focal length** separated by a distance equal to two-thirds of their common focal length. The real image of the objective lens and the cross-hairs should be placed about one-fourth the common local length from the field lens of the eyepiece. Two plane convex lenses with convex sides adjacent to each other will give decreased **aberrations.** The total **magnifying power** of a Ramsden eyepiece is equivalent to that of a single lens of a focal length three-fourths of that of either of the two lenses.

EYKMAN FORMULA. An empirical relationship for the molal refraction of a liquid, of the form:

$$R = \frac{M(n^2 - 1)}{d(n + 0.4)} = \frac{V(n^2 - 1)}{n + 0.4}$$

in which R is the **molal refraction** for a given optical frequency, n is the **index of refraction** for that frequency, M is the molecular weight, V is the **molecular volume,** and d is the density.

EYRING FREE VOLUME THEORY. A theory that seeks to account for the properties of a liquid by assuming that each liquid molecule may move freely within a certain free volume, but in the liquid state all holes **are** available to the molecules, in distinction to the solid state.

EYRING GENERAL ENERGY EQUATION. The energy level in a room, initially at E_0, is given as a function of the time t (measured from the cutting off of the sound source) as

$$E = E_0 e^{\frac{cs}{4V} \log (1 - \bar{\alpha}) t},$$

where $\bar{\alpha}$ = average sound absorption coefficient of the walls, c = velocity of sound, s = surface area of room, V = volume of room.

EYRING TREATMENT OF DIFFUSION. Diffusion takes place through the formation of holes in the liquid into which the diffusing molecules can move. The ratio of the **diffusion coefficient** to the **fluidity** is proportional to the absolute temperature, i.e., the activation energy for diffusion is equal to the **activation energy for liquid flow.**

EYRING TREATMENT OF VISCOSITY. The rate of yielding of a liquid in response to an applied shear stress is assumed to be proportional to the rate of formation of holes in the liquid. It follows that the **activation energy for liquid flow** should be of the same order of magnitude as the heat of vaporization.

F

F. (1) Function (f). (2) Force (F or f). (3) Formality (F). (4) Frequency (f). (5) Photoelectric threshold frequency (f_0 but ν_0 is preferred). (6) Fugacity (f). (7) Faraday constant or equivalent (F). (8) Farad (unit of electrical capacity) (f or F). (9) Faraday (unit of electrical quantity) (F). (10) Magnetomotive force ($\mathfrak{F}$). (11) Degree of freedom (F or f). (12) Free energy, a common usage, but G is used in this book (F). (13) Resonant frequency (f_r). (14) Distribution function (f or F). (15) Focal length of object space (f). (16) Focal length of image space (f'). (17) Hyperfine quantum number (F). (18) Luminous flux (F). (19) Relative humidity (f). (20) Narrow, fine spectral structure (f). (21) Type of electron with an azimuthal quantum number of 3 (f). (22) Spectral term symbol for L-value of 3 (F). (23) Hyperfine quantum number, sum of J and I (F). (24) Rotational part of the energy of a molecule (F). The usage in (24) assumes separability of the energy into three parts, $T = T_e + G + F$, expressed in kaysers or megacycles. (25) Abbreviation for filament on diagrams of vacuum-tube circuits (f or F).

F-BAND. The optical absorption band characteristic of **F-centers** in alkali halide crystals.

F-CENTER. The simplest type of **color center** in an alkali halide crystal, consisting of a **negative ion vacancy** to which is bound an excess electron moving as if in a hydrogen atom orbit about the positively charged center. The name comes from the German *Farbzenter.*

$F_2{}^+$ CENTER. See **color center.**

F_2 LAYER. The single ionized layer normally existing in the **F region** in the night hemisphere, and the higher of the two layers normally existing in the **F region** in the day hemisphere.

F-LINE. Fraunhofer line at 4861.3 Å caused by hydrogen in the atmosphere of the sun.

F-NUMBER. See **F/system.**

F REGION. The region of the **ionosphere** above the **E region.**

F²-SERIES. See **Patterson-Harker method.**

f-SUM RULE OF THOMAS-REICHE-KUHN. The expression:

$$\sum_a f_a - \sum_e f_e = Z$$

where the first sum refers to all possible absorption transitions of a given atom in a given state, and the second sum to all emission transitions of this state, and Z is the number of **"effective" electrons** per atom (For neon, Z is between one and two, since only one, or at the most, two electrons take part in absorption.)

F/SYSTEM. A method of designating the relative aperture of photographic lenses. The f number expresses the ratio of the diameter of the effective diaphragm aperture to the focal length of the lens. Thus, with a lens having an effective diaphragm of 1″ and a focal length of 8″, the ratio is 1:8 which is written $f/8$. Following the recommendation of a committee of the Royal Photographic Society of Great Britain, at ratios greater than 1:4 ($f/4$) lenses are marked so that the exposures increase as the power of 2. Thus:

f/number	4	5.6	8	11.3	16	22
Relative exposure . . .	1	2	4	8	16	32

The difference in exposure for two f/values is the ratio of the squares of the numbers. The difference in exposure, for example, in $f/4$ and $f/16$ is

$$\frac{16^2}{4^2} = \frac{256}{16} = 16.$$

FABRY AND BAROT METHOD. While the simplicity of the method of minimum deviation (see **deviation, angle of minimum**) makes it the most common technique for determining the index of refraction of a prism, Fabry and Barot developed a method which has certain definite advantages when working in the in-

visible ultraviolet or infrared. The prism of angle A is set up in a fixed position so that the entrant beam is normal to the emergent face. This can be done with visible light. Then the index of refraction of the prism for radiation detected (photographic or infrared **detector**) at an angle of deviation D is given by

$$n^2 = 1 + 2 \cot A \sin D + \frac{\sin^2 D}{\sin^2 A}.$$

(See *Revue d'Optique* **7**, 429 (1928).

FABRY AND PEROT ETALON. A multiple-reflection instrument of very high resolving power, simpler than the Michelson type of **interferometer**. (See Robertson, *Introduction to Optics*, 4th Ed., page 172 ff.)

FABRY-PEROT INTERFEROMETER. A multiple-beam **interferometer** consisting of two parallel plates of glass or quartz separated a short, known distance, and with the adjacent surfaces partially silvered so as to increase reflection without being fully opaque. This instrument is capable of very high **resolution** of two, very close spectral lines.

FACE-CENTERED STRUCTURE. A type of **crystal structure** in which atoms occupy the corners, and centers of the faces of a cube or other parallelepiped The face-centered cubic structure is **close-packed.**

FACSIMILE TRANSMISSION. See **transmission, facsimile.**

FACTOR OF SAFETY. A number expressing the relation between the utmost endurance of a structural part, or of a complete structure, to the maximum actual demand that may be expected ever to be made upon it. It is a combination of allowances made in the use of data.

FACTOR THEOREM OF ALGEBRA. If $(x - r)$ is a factor of a **polynomial** $P(x)$, then $x = r$ is a **zero** of the polynomial function $P(x)$, and a **root** of the polynomial equation $P(x) = 0$. Conversely, if $x = r$ is a zero of the polynomial or a root of the equation, then $(x - r)$ is a factor of $P(x)$.

FACTORIAL. If n is a positive integer, **factorial** n means the product $1 \cdot 2 \cdot 3 \cdots n$. It may be denoted by the symbols $\underline{|n}$ or $n!$, but the latter form is generally preferred. By convention, $0! = 1$. Generalization of such a product to include negative numbers or those which are not integers results in the **gamma function.**

FADE. (1) In broadcast terminology, to change signal strength gradually. (2) To undergo partial loss of color of a substance or material on exposure to radiation.

FADE IN. To **fade** to a higher signal level.

FADE OUT. (1) To **fade** to a lower signal level. (2) A disruption of radio communications due to severe **ionospheric** disturbances.

FADEOMETER. An instrument for determining the resistance to fading of substances and materials upon exposure to the action of radiant energy (commonly artificial sunlight or ultraviolet light) under controlled conditions.

FADER. A multiple-volume control used to **fade out** one channel as another channel is being **faded in.** The **signal level** is constant at all times.

FADING. The fading of radio signals is inherent in the transmission of such signals and at best can only be partially compensated for in the receiver by **avc** circuits, **diversity** reception, etc The compensation may often be made entirely satisfactory if the fading is of the simplest type, but if it is selective, compensation is not always satisfactory. Radio waves going out from the transmitter travel along various paths to the **receiver,** some of the waves travel along the ground, others are reflected from the **ionosphere.** In the broadcast band fading is usually caused by signals which have been reflected from the ionosphere combining vectorially with signals which have traveled along the earth (these are called respectively **sky wave** and **ground wave**). The sky wave does not return to the earth near the transmitter so there is no fading in this region, and at great distances from the transmitter the ground wave has died out so again there is no fading due to this cause. In the intermediate region both waves may be present and, if the phase of the two signals is such that they cancel, fading results. Since the ionosphere is continually changing, the phase of the reflected sky wave may cause cancellation at one instant and addition of the signals at the next. Different frequencies travel somewhat different paths in the ionosphere so the time to reach the receiver is different for the different sideband frequen-

cies. Thus one frequency may reach the receiver to add to the ground wave, while another may cancel. This produces what is known as selective fading and the output of the receiver is badly distorted. The other type of fading, in which all portions of the modulated wave are attenuated by the same amount, is called amplitude fading

FAHRENHEIT SCALE. (F.) A thermometric scale devised by Fahrenheit (1686–1736), on which the freezing point of water is 32 degrees, and the boiling point 212 degrees, both at standard pressure. (See also **temperature scale, Fahrenheit.**)

FAIRBAIRN AND TATE METHOD FOR VAPOR PRESSURE. Two glass bulbs A and B contain different amounts of the liquid, that in A being less than that in B, and the spaces above the liquid contain only saturated vapor. The lower ends of the bulbs communicate through a tube containing mercury which thus seals the liquid in the bulbs, and allows the pressure difference between the bulbs to be measured. On warming the apparatus, a point will come when B still contains liquid, while that in A has just disappeared The difference in pressure, which has hitherto been zero, will now increase suddenly, since the pressure of the saturated vapor in B increases more rapidly with temperature than the pressure of the unsaturated vapor in A. Knowing the mass of substance in A, and the volume of the bulb, the saturated density of vapor can be calculated.

FALL TIME. See **time constant.**

FALL-WIND. A wind blowing down a mountainside; or any wind having a strong downward component. Fall-winds include the Foehn, mistral, bora, etc.

FALSE CIRRUS. Cirrus resulting from anvil heads of **thunderstorms.**

FALTUNG THEOREM. See **convolution.**

FAMILY. A group of **elements** characterized by similar chemical properties such as **valence,** solubility of salts, behavior toward reagents, etc. The alkali family includes sodium, potassium, lithium, rubidium, cesium, and francium. The halogen family consists of fluorine, chlorine, bromine, iodine, and astatine.

FAMILY, RADIOACTIVE. See **radioactive series.**

FAN-TYPE MARKER. See **radio range.**

FANNED-BEAM ANTENNA. See **antenna, fanned-beam.**

FAR FIELD. The acoustic radiation field (see **sound field**) at large distances from the source.

FAR POINT OF THE EYE. The nearest point on which the eye is focused when fully relaxed.

FARAD. A unit of capacitance, abbreviation f or fd. The farad is the capacitance of a **capacitor** (or condenser) which acquires a charge of one coulomb when a steady potential difference of one volt is maintained across its terminals. The microfarad (10^{-6} f) and the micromicrofarad (10^{-12} f) are used as units of capacitance much more often than is the farad.

FARADAY CYLINDER. See **Faraday ice-bucket experiment.**

FARADAY DARK SPACE. The nonluminous region between the **negative glow** and the **positive column** in a **gas-discharge tube** (Crookes tube) at moderate pressure

FARADAY DISC MACHINE. A copper disc, rotated so that it "cuts" the **flux** between the poles of an electromagnet, serves as a low voltage d-c generator by virtue of the induced, radial electromotive force One output brush contacts the axle; the other, the rim beyond the magnet pole-gap.

FARADAY EFFECT. When a transparent isotropic medium is in a strong magnetic field there is a rotation of the plane of vibration of polarized light which is transmitted through the medium in the direction of the field The direction of rotation depends on whether the velocity of the light is parallel or antiparallel to the magnetic field. The angle of rotation α is given by

$$\alpha = \omega lH$$

where l is the length of the path traversed in a magnetic field of strength H and ω (sometimes C) is known as the **Verdet constant.** The Faraday effect is one of the special cases mentioned under **rotation of the vibration plane.** (See Robertson, *Introduction to Optics,* 2nd ed.)

FARADAY ICE-BUCKET EXPERIMENT. If a metal bucket is connected to a gold-leaf **electroscope,** and a charged metal body lowered into the pail without contact, the electroscope leaves repel each other. When the charged body is well inside the pail, the leaves have attained a maximum separation, and further motion into the pail has no effect. If the charged body is touched to the bottom of the pail, there is still no change, but upon withdrawal of the body the leaves retain their maximum separation. Furthermore, the body is found to have lost all its charge.

FARADAY LAWS OF ELECTROLYSIS. (1) The amount of chemical decomposition produced by a current, that is, the amount of any substance deposited or dissolved, is proportional to the quantity (charge) of electricity passed. (2) The amounts of different substances deposited or dissolved by the same quantity of electricity are proportional to their chemical equivalent weights (the equivalent weight of an element is its **atomic weight** divided by its **valence** in the particular state in question).

FARADAY LAW OF ELECTROMAGNETIC INDUCTION. The **electromotive force** induced in a circuit is

$$\mathcal{E} = -\frac{d\phi}{dt}$$

where ϕ is the **magnetic flux** linking the circuit. (See also **electromagnetic induction.**)

FARADAY SHIELD (SCREEN). An electrostatic shield made of a series of parallel wires connected at one end. The common point is grounded. Electromagnetic waves are not influenced by the screen.

FARBZENTER. See **F-center.**

FARNSWORTH IMAGE DISSECTOR TUBE. See **image dissector.**

FAST FISSION FACTOR. In **reactor** theory, the ratio of the total number of fast neutrons produced by fissions due to neutrons of all energies, to the number resulting from thermal neutron fission.

FATHOMETER. An instrument employing sonic echo ranging (see **sonar, direction and ranging**) to determine and record the depth of the sea.

FATIGUE. (1) The tendency for a metal to fracture under repeated stressing considerably below the ultimate tensile strength. In a common method of test, a polished specimen is rotated rapidly and subjected to alternate flexure. The fatigue limit or endurance limit of a metal or alloy is that stress below which failure will presumably not occur in an infinite number of cycles. When such a limit does not exist, the term is often applied to the stress causing fracture in a specified large number of cycles. The endurance ratio is the endurance limit divided by the tensile strength. For most carbon and alloy steels this ratio is approximately 0.5 while for nonferrous alloys it may be less than 0.25 or greater than 0.5. Sharp notches reduce the endurance limit of most materials. Corrosion of the metal surface during the cyclic stressing leads to corrosion fatigue, and causes a pronounced decrease in the endurance limit in many metals. (2) See also **fatigue, elastic.**

FATIGUE, ELASTIC. An increase in the **damping factor** of an elastic solid which occurs after a large number of oscillations. If the substance is permitted to rest, recovery takes place and the damping factor returns to its normal value. (See **damped harmonic oscillator.**)

FAULT ELECTRODE CURRENT (SURGE ELECTRODE CURRENT). The peak current that flows through an electrode under fault conditions, such as arc-backs and load short-circuits.

FCC. Abbreviation for Federal Communications Commission.

FEATHER ANALYSIS. A technique established by N. Feather (1938) for the determination of the range in aluminum of the β-rays of a species by comparison of the absorption curve with the absorption curve of a reference species, usually Bi^{210} (RaE). It is assumed that the **attenuation** of the β-beam by the amount of absorber, expressed as a fraction of the range, is the same in the limit, for the β-particles under study as those of Bi^{210}. Taking the range for Bi^{210} as 476 mg/cm² of aluminum the attenuations of Bi^{210} radiations at 0.1, 0.2, 0.3, $\cdots$ of this amount of absorber are used to identify trial values of the range of the species under study. These trial values are plotted against the numbers 0.1, 0.2, 0.3, $\cdots$ and extrapolated to obtain a value at 1.0.

Maximum β-energies may be estimated from these extrapolated range values, as for instance by an empirical equation given by Feather. (See **range-energy relationships.**)

FECHNER COLORS. Visual sensations of color induced by intermittent **achromatic stimuli.**

FECHNER FRACTION. If the eye can just distinguish an object whose **brightness** differs by an amount dB from a large field of brightness B, the contrast sensitivity may be measured by dB/B, sometimes called the Fechner fraction.

FECHNER LAW. See **Mackenzie equation.**

FEED. To provide a signal at some point.

FEEDBACK. (1) Feedback, or the transfer of energy from a high level point to a low level point, in communications circuits may be either positive or negative. Positive feedback is that in which the signal fed back is in phase with the input signal; thus we might say that some of the output is sent back through the circuit to add to the regular signal present. For **amplifiers** this effect is normally very undesirable, although in some amplifiers it is used to increase the gain. If enough energy is fed back positively the input can be removed entirely and the signal kept going through the amplifier by the feedback. This is possible since a small signal at the input produces a much larger one at the output and only a small part of this needs to be returned to the input to keep the process going. When this condition is reached the amplifier oscillates or howls. While smaller amounts than this may be used, to increase the gain of an amplifier it is always at the expense of stability and fidelity. An **oscillator** is really an amplifier with a large amount of positive feedback. Negative feedback is that in which the signal fed back to the input is in phase opposition with the input. While this cancels part of the input it has such desirable effects that it is almost universally used for high-grade amplifiers. Negative, or inverse, feedback increases the stability, improves the frequency response, lowers distortion and noise and has other similar desirable results. The improvement along these lines is approximately proportional to the amount of feedback, but a compromise value which will not decrease the gain too much and yet give decided improvement in the other characteristics is used. Since many feedback circuits have phase and amplitude characteristics which vary with frequency, an amplifier may have negative feedback at one frequency and positive at another. If the amplifier has sufficient gain in the positive feedback region it will oscillate. If the signal fed back is proportional to the output current it is termed current feedback and stabilizes the current, while if it is proportional to the output voltage it is voltage feedback and stabilizes the voltage.

(2) In a magnetic amplifier, feedback is a circuit connection by means of which an additional **magnetomotive force,** which is a function of the output quantity, is used to influence the operating condition

FEEDBACK, CURRENT (EXTERNAL FEEDBACK). In a magnetic amplifier, a feedback in which the output quantity employed is the rectified output current. Simple series magnetic amplifiers using this type of feedback are often referred to as external feedback magnetic amplifiers; however, this nomenclature is discouraged.

FEEDBACK, ELECTRIC. See **electric feedback.**

FEEDBACK, INDUCTIVE. Feedback through an **inductive-coupling** network.

FEEDBACK RATIO, NOMINAL. Of a simple series magnetic amplifier with current feedback, the ratio of the number of turns of the feedback winding to the number of turns of the output winding.

FEEDBACK SIGNAL. A signal responsive to the value of the **controlled variable** in an **automatic controller.** This signal is returned to the input of the system and compared with the reference signal to obtain an actuating signal which returns the controlled variable to the desired value.

FEEDBACK, STABILIZED. Feedback employed in such a manner as to stabilize the **gain** of a **transmission system** or section thereof with respect to time or frequency or to reduce noise or distortion arising therein. The section of the transmission system may include **amplifiers** only, or it may include **modulators.**

FEEDBACK WINDINGS. Of a saturable reactor, those control windings to which the feedback connections are made.

FEEDER. (1) In **electrical circuits,** the lines running from a main switchboard to branch panels in an installation (2) In **radio circuits,** the transmission line from the transmitter to the antenna.

FEELING, THRESHOLD OF SOUND (OR DISCOMFORT, TICKLE, OR PAIN). For a specified **signal,** the minimum effective **sound pressure** of that signal which in a specified fraction of the trials will stimulate the ear to a point at which there is the sensation of feeling (or discomfort, tickle, or pain). Characteristics of the signal and the measuring technique should be specified in every case. This threshold is customarily expressed in **decibels** relative to 0.0002 **microbar** or to 1 microbar.

FELICI BALANCE. An **a-c bridge** for the measurement of **mutual inductance.**

FENESTRATION. A surgical operation in which a new window is opened to the inner ear in order to improve hearing.

FERGUSON CLASSIFICATION OF BRIDGES. See **bridges, Ferguson classification of.**

FERMAT PRINCIPLE. A ray of light from one point to another, including reflections and refractions, will follow that path which can be followed in the least time. Hence also called the principle of least time. In most general form also called the law of extreme path.

Mathematically

$$\delta \int_A^B n\, ds = 0$$

in the notation of the calculus of variations, n being the index of refraction at the location of the element of path ds.

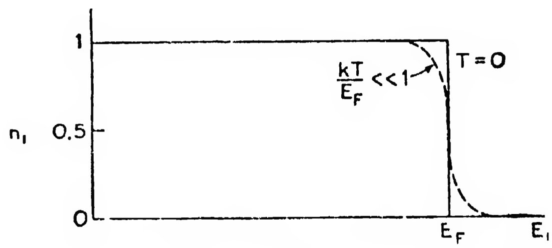
FERMI-AGE MODEL. A model for the study of the slowing down of **neutrons** by elastic **collisions.** It is assumed that the slowing down takes place by a very large number of very small energy changes. Phenomena due to the finite size of the individual energy losses are ignored.

FERMI CONSTANT. A universal constant appearing in **β-disintegration theory,** expressing the strength of the interaction between the transforming nucleon and the electron-neutrino field. Its value is between 10^{-48} and 10^{-49} g cm^5 sec^{-2}, and it is usually denoted by the symbol g or G. (See also **coupling constant.**)

FERMI-DIRAC DISTRIBUTION FUNCTION. In a **Fermi-Dirac** gas the number of particles, n_i, in a state of energy E_i, at the absolute temperature T is

$$n_i = \frac{1}{e^{(E_i - E_F)/kT} + 1}$$

where k is the **Boltzmann constant** and E_F is the **Fermi energy.** If $kT \ll E_F$ this function is nearly unity for $E_i < E_F$ and nearly



Sketch of Fermi Dirac distribution function for absolute zero and for a low temperature. The region over which the distribution is affected by temperature is the order of the kT in width. (By permission from "Introduction to Solid State Physics" by Kittel, Copyright 1953, John Wiley & Sons)

zero for $E_i > E_F$. The gas is then said to be degenerate, and only the particles in the range of energy levels of width kT about E_F are available for conduction, etc.

FERMI-DIRAC GAS. An assembly of independent particles obeying **Fermi-Dirac statistics.** The essential property of such particles is that they obey the **Pauli exclusion principle** of quantum mechanics, which requires that no two particles may be in exactly the same **state.** If the gas is very dense, this requirement may mean that the particles must occupy a wide range of **energy levels,** much larger perhaps than can be supplied by thermal energy. It can be shown by statistical mechanics that in such a **degenerate gas** (of which the **free electrons** in a metal are the standard example) only a small proportion of the particles contribute to such properties as

the **susceptibility, specific heat, conductivity,** etc.

FERMI-DIRAC STATISTICS. See **quantum statistics.**

FERMI DISTRIBUTION. The energy distribution of the electrons in a metal. Because the electrons constitute a highly degenerate **Fermi-Dirac gas,** this distribution is simply characterized as one in which all the levels are filled below the **Fermi level,** and all empty above it, except for a thin layer, of thickness of the order of kT, about this level. (See **Fermi-Dirac distribution function.**)

FERMI ENERGY. According to the **free electron theory of metals** the electrons form a dense **Fermi-Dirac gas,** whose energy is very high even at very low temperatures. The Fermi energy is a measure of this, but the term seems to be used indiscriminately to refer either to (a) the energy E_F occurring as a parameter in the **Fermi-Dirac distribution function** and measuring the highest occupied level at very low temperatures, or to (b) the average energy of the electrons, which is $3/5$ E_F. In most metals the Fermi energy is of the order of a few electron volts. The usage (b) is recommended, (a) being referred to as the **Fermi level** (it being, in fact, the **chemical potential** of the electrons).

FERMI INTERACTION. UNIVERSAL. See **universal Fermi interaction.**

FERMI LEVEL. The point on an **energy level diagram** corresponding to the top of the **Fermi distribution;** or the energy level (in a semi-conductor) for which the Fermi-Dirac distribution function has a value of $1/2$

FERMI PERTURBATIONS. See **Fermi resonance.**

FERMI PLOT. See **Kurie plot.**

FERMI POTENTIAL. The energy of the **Fermi level** interpreted as an electric potential, i.e., the ratio of the **Fermi level** to the electronic charge.

FERMI RESONANCE. In polyatomic molecules, two vibrational levels belonging to different vibrations (or combinations of vibrations) may happen to have nearly the same energy, and therefore be accidentally **degenerate.** As was recognized by Fermi in the case of CO_2 such a "resonance" leads to a **perturbation** of the energy levels that is very similar to the vibrational perturbations of diatomic molecules.

FERMI SELECTION RULES. See **selection rules.**

FERMI SURFACE. The constant-energy surface, pictured in the same space as a **Brillouin zone,** corresponding to the **Fermi level,** of which it is, in a sense, the three dimensional analog.

FERMI TEMPERATURE. The degeneracy temperature of a **Fermi-Dirac gas,** defined by E_F/k, where E_F is the energy of the **Fermi level,** occurring as a parameter in the **Fermi-Dirac distribution function.** For the free electrons in a metal, this temperature is of the order of tens of thousands of degrees, so that the gas is highly degenerate.

FERMI THEORY OF BETA DECAY. The Fermi theory of β-decay was proposed in 1934. It gives the probability P of the ejection, in unit time, of a β-particle whose energy lies between E and $E + dE$ as

$$PdE = kf(Z, E)pE(E_{max} - E)^2dE$$

where p is the momentum of the electron. Here E is expressed in units of mc^2 and p in units of mc. $f(Z, E)$ is a function which could be evaluated.

FERMION. A particle described by Fermi-Dirac statistics (See **quantum statistics.**)

FERRAMIC. The trade name of one form of **ferrite.**

FERREL LAW. When a mass of air starts to move over the earth's surface, it is deflected to the right in the Northern Hemisphere, and to the left in the Southern Hemisphere, and tends to move in a circle whose radius depends upon its velocity and its distance from the equator. (See **Coriolis effects.**)

FERRIMAGNETISM. A type of magnetism, macroscopically similar to **ferromagnetism,** but microscopically more like **antiferromagnetism** in that the magnetic moments of neighboring ions tend to align antiparallel. These moments are, however, of different magnitudes, and hence may still have quite a large resultant magnetization. Ferrimagnetism is observed in the **ferrites and similar compounds.**

FERRITE. The inorganic salts of the formula MFe_2O_4, where M represents a bivalent metal. Almost all of these materials are magnetic, and cores made of sintered powders find considerable high-frequency application because of the extremely low **core losses.**

FERROELECTRIC. Some **dielectric** materials, notably Rochelle salt, potassium dihydrogen phosphate, and barium titanate, exhibit spontaneous **polarization** and **hysteresis** between **polarization** and **field.** By analogy with **ferromagnetic** materials, these substances are called ferroelectric.

FERROELECTRIC EFFECT. The phenomenon whereby certain crystals may exhibit a spontaneous **dipole moment** (which is called ferroelectric by analogy with **ferromagnetic** exhibiting a permanent magnetic moment). The effect in the most typical case, barium titanate, seems to be due to a **polarization catastrophe,** in which the local electric fields due to the polarization itself increase faster than the elastic restoring forces on the ions in the crystal, thereby leading to an asymmetrical shift in ionic positions, and hence to a permanent dipole moment. Ferroelectric crystals often show several **Curie points, domain structure hysteresis,** etc., much as do ferromagnetic crystals.

FERROELECTRIC MATERIALS. The dielectric analog of **ferromagnetic** materials. Their uses parallel those of ferromagnetic materials in such applications as **magnetostrictive transducers, magnetic amplifiers,** and magnetic information storage devices. Rochelle salt was the first ferroelectric material to be discovered.

FERROMAGNETIC RESONANCE. The **apparent permeability** of a magnetic material at **microwave frequencies** is affected (in the presence of a transverse, steady field) by the precession of electron orbits in the atoms. If the microwave frequency equals the precession frequency, **resonance** occurs and the apparent permeability reaches a sharp maximum. The resonance frequency depends upon the strength of the transverse field. Thus, a thin film of a ferromagnetic substance placed in a static magnetic field H is found to be capable of absorbing from an oscillating field whose magnetic vector is perpendicular to H at a frequency given by

$$\omega = \left(\frac{ge}{2mc}\right)(BH)^{1/2}$$

where B is the magnetic induction associated with H, e and m are the charge and mass of the electron, c is the velocity of light, and g is very near to 2, the **Landé factor** for free electrons.

FERROMAGNETISM. The property of certain materials that gives them **relative permeabilities** noticeably exceeding unity, in practice from 1.1 to 10^6. Such materials generally exhibit **hysteresis,** hence can be used for permanent magnets.

FERROMAGNETISM, EWING THEORY OF. See **Ewing theory of ferromagnetism.**

FERROMAGNETISM, WEISS THEORY OF. See **Weiss theory of ferromagnetism.**

FERRORESONANT CIRCUIT. A non-linear resonant circuit employing a **capacitor** and an **inductor** with a saturable core. Operation equivalent to that of resonance is achieved by varying circuit voltage (or current) at a specified frequency to some critical value which causes the non-linear inductance to have the correct value of reactance to resonate with the capacitor. At the point of resonance, the current (or voltage) jumps abruptly to a much higher value.

FERROSPINEL. A **ferrite.**

FERROXCUBE. Trade name for a **ferrite.**

FERRY-PORTER LAW. The critical fusion frequency (the frequency at which a flicker disappears) for the **fovea** of the eye is proportional to the logarithm of the **luminance.**

FERTILE MATERIAL. Material which is not in itself fissionable, but which, in a reactor, may be transformed into fissionable material through a nuclear transformation; e.g.:

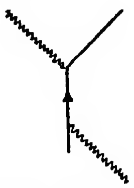
$$Th^{232} + n \rightarrow Th^{233} \xrightarrow[23\text{ min}]{\beta^-} Pa^{233} \xrightarrow[27.4\text{ days}]{\beta^-} U^{233},$$

the U^{233} is fissionable.

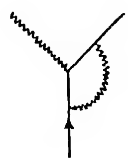
FÉRY PRISM. See **prism, Féry.**

FESSENDEN OSCILLATOR. A low-frequency, moving-coil, electromagnetic **sound** generator, principally used as a low-frequency, underwater **sound source.**

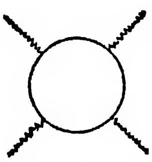
FEYNMAN DIAGRAM. Sketch in **Minkowski space** of the development of a process involving the interaction of particles and/or electromagnetic radiation, including a pictorial representation of the intermediate states through which the system may go. An electron is represented by a **time-like** line with an arrow pointed towards the future, and a positron by such a line with an arrow pointed towards the past. Particularly useful for representing many different intermediate states on the one diagram and, since with each diagram is associated a matrix element for some transition, for arriving more directly at the cross-section for a process. Some examples are given below, a photon being denoted by a wavy line:



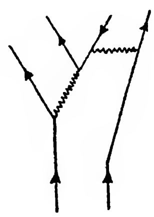
Compton Scattering (Lowest Order)



A Radiative Correction to Compton Scattering



The Scattering of Light by Light



Pair Production in Electron-Electron Collisions

(See **quantum electrodynamics; quantized field theory.**)

FICK LAW. See **diffusion, Fick law.**

FICK DIFFUSION COEFFICIENT FOR NEUTRON FLUX. The **Fick law** of diffusion **(as applied to neutron flux)** is

$$\mathbf{J} = -D \operatorname{grad} \phi$$

where **J** is the net number of (thermal) neutrons flowing in unit time through a unit area normal to the direction of flow, ϕ ($= nv$) is the neutron flux, and D is the diffusion coefficient for flux, having the dimensions of length, and being equal to D_0/v, where D_0 is the conventional diffusion coefficient, and v is the neutron velocity.

FIDELITY. The degree with which a system, or a portion of a system, accurately reproduces at its output the essential characteristics of the signal which is impressed upon its input.

FIELD. (1) For the most generalized conceptions of this term, see the discussions of the various **field theories.** (2) A **field of force.** (3) An **electromagnetic field.** (4) A sound field (see **field, sound**). (5) A **field of view.** (6) In electric motors and generators, the field is the part of the machine which furnishes the magnetic flux which reacts with the armature to produce the desired machine action. The field may be the fixed part of the machine or, as is usually the case in synchronous motors and generators, the field may be the rotating part of the machine. (7) The energy radiated from an antenna system of a radio transmitter. This field is electromagnetic, consisting of both an electric and magnetic component. It is the interaction of these fields with the receiving antenna which causes the signal voltage to be induced in the antenna, and hence introduced into the main receiver-circuit. (8) In television, one of the two (or more) equal parts into which a **frame** is divided in **interlaced scanning.**

FIELD, ATOMIC. The region surrounding an atom in which the **repulsion forces** for other particles are considerable.

FIELD COIL. The coil used to provide the magnetizing force in motors, generators, electrodynamic loudspeakers, etc.

FIELD, ELECTRIC. The attraction (or repulsion) exerted by one electric charge on another can be described quantitatively in terms of the electric field produced by the first charge. By definition, the field at any point is the force (a vector, having magnitude and direction) that would be exerted on a unit positive test charge placed at that point. Hence an electric field is a specific type of force field. The path that would be followed by an inertia-less test particle is called a "line of force." It follows from the **Coulomb law** that the field of a point charge in free space has the magnitude

$$E = \frac{q}{\epsilon_0 r^2}.$$

where q is the charge, ϵ_0 is the **permittivity,** r is the distance from the charge, and unrationalized units are employed. (See **flux, electric.**)

FIELD EMISSION. The emission of electrons from unheated metal surfaces, produced by sufficiently strong electric fields.

FIELD, FREE. A field (wave or potential) in a homogeneous, isotropic medium free from boundaries. In practice it is a field in which the effects of the boundaries are negligible over the region of interest. In acoustics, the actual pressure impinging on an object (e.g., electroacoustic **transducer**) placed in an otherwise free **sound field** will differ from the pressure which would exist at that point with the object removed, unless the acoustic impedance (see **impedance, acoustic**) of the object matches the acoustic impedance of the medium.

FIELD-FREE EMISSION CURRENT (OF A CATHODE). The electron current drawn from the cathode when the electric gradient at the surface of the cathode is zero.

FIELD FREQUENCY. In television the product of **frame frequency** multiplied by the number of **fields** contained in one **frame.**

FIELD, IMPRESSED. (See **field, reflected.**) The **electromagnetic field** which would exist if the body of interest were not present, or the field that would exist in free space with the given source distribution.

FIELD, INDUCTION. See **induction field.**

FIELD INTENSITY. See **field strength.**

FIELD INTENSITY, FREE-SPACE. The **field intensity** that would exist at a point in the absence of waves reflected from the earth or other reflecting objects. Used in the discussion of electromagnetic or acoustic radiation.

FIELD LENS. The lens of a compound **ocular** farthest from the eye, the other lens being called the eye lens. (See **eyepiece, Huygens; Ramsden.**)

FIELD, MAGNETIC. See **magnetic field.**

FIELD OF FORCE. Electric charges exert force upon other electric charges, magnets exert forces upon other magnets, matter exerts gravitational force upon other matter. All these action-at-a-distance phenomena are conveniently described in terms of the "force field" set up by a source. The force exerted on a unit test-particle (unit charge, unit pole, unit mass) is a vector function of position of the test-particle. That is, the force on a unit test-particle has a definite magnitude and direction for each possible location of the test-particle. The totality of these force vectors, or the vector function of position, is called a "field of force." Any path that would be followed by an inertia-less test-particle in a force field is called a "line of force." It is convenient to decide arbitrarily how close together possible lines of force are independent, so that there will be a finite number of lines, and the concept can be made quantitative. Conventionally a unit source radiates 4π lines, or one per unit solid angle in unrationalized systems, and a single line ($1/4\pi$ per unit solid angle) in rationalized systems.

FIELD OF PLANE MIRROR. The words applied to an optical system apply to a plane mirror. The **exit pupil** is the pupil of the observer's eye, the **entrance pupil** is the behind-the-mirror **virtual image** of the observer's eye pupil. The **field stop** is the edge of the mirror. The region in front of the mirror is the **object field,** and the region behind the mirror is the **image field.**

FIELD OF VIEW. The area or solid angle visible through an optical instrument.

FIELD OPERATOR. In quantized field theory, an operator which represents the creation or annihilation of a particle.

FIELD, PSEUDO-SCALAR. See **pseudoscalar field.**

FIELD, PSEUDO-VECTOR. See **pseudovector field.**

FIELD, REFLECTED. The **electromagnetic field** in the presence of perturbing objects or regions of a different medium is conveniently considered to comprise an **impressed field** that would obtain in the absence of the perturbation, plus a field reflected from the object, and a field transmitted into the object. The difference between the actual field (outside the object) and the impressed field is the reflected field.

FIELD, SCALAR. See **scalar field.**

FIELD, SOUND. A region containing **sound waves.**

FIELD STOP. An opening, usually circular, in an opaque screen which determines the **field of view** of an optical instrument.

FIELD STRENGTH. The strength of a field is its magnitude. Thus an electric field has a strength (volts per meter) at a given point, as well as a direction; its strength is, therefore, the magnitude of its **electric field vector, E.** (See **fields of force.**)

FIELD STRENGTH METER. A calibrated radio receiver for measuring **field strength.**

FIELD THEORY. Theory of the dynamical motion of a set of electromagnetic or matter fields, in which the electromagnetic potentials A_μ and the matter wave functions ψ_a are represented by functions of position and time. Usually but not always a field theory is developed in accordance with the postulates of special relativity theory (see **relativity theory, special**) so that if it is designed to describe nuclear forces the principle of relativity will be extended to include the impossibility of detecting absolute uniform motion of the laboratory by means of nuclear experiments conducted therein. In this type of field theory the equations of motion are derived from a **Lagrangian density**

$$L\left(\psi_a, A_\mu, \frac{\partial \psi_a}{\partial x_\nu}, \frac{\partial A_\mu}{\partial x_\nu}\right)$$

being, for the ψ_a,

$$\sum_{\mu=1}^{4} \frac{\partial}{\partial x_\mu}\left(\frac{\partial L}{\left(\frac{\partial \psi_a}{\partial x_\mu}\right)}\right) = \frac{\partial L}{\partial \psi_a}.$$

For other properties of L see **gauge invariance, energy-momentum tensor.** Since it is possible to derive the **Maxwell equations** and the **Dirac electron theory** in this way, it has been hoped to formulate in analogous fashion a satisfactory **meson theory of nuclear forces.**

Field theories may also be developed in accordance with general relativity theory (see **relativity theory, general** and **field theories, unified**) and for non-relativistic theories (e.g., **sound waves,** theory of an oscillating string or membrane). (See also **field theory, quantized.**)

FIELD THEORY, NON-LOCAL. Field theory in which the **Lagrange density** involves products of wave-functions taken at different space-time points and multiplied by a **form factor** which causes the term to be important only when such points are close to each other. This provides a method of introducing a relativistic **cut-off** at the very beginning of the development of the theory.

FIELD THEORIES, PROJECTIVE. Unified **field theories** of gravitation and electromagnetism in which 4-dimensional space-time is represented by 5 homogeneous coordinates. All points in 5 dimensions which have the same coordinate-ratios project into the same point in 4 dimensions. Such theories are essentially equivalent to the **Kaluza theory.**

FIELD THEORY, QUANTIZED. Field theory in which the electromagnetic and matter fields are represented by operators obeying certain **commutation relations** (see also **Jordan-Wigner commutation relations**). This quantization of the fields is developed by analogy with the passage from **classical mechanics** to **quantum mechanics** and is most easily described by reference to the theory of a vibrating string. Considered as a set of discrete mass points, such a string may be described by classical particle mechanics, but in the limit when it is considered as a continuous medium the number of **degrees of freedom** tends to infinity and the equations of motion are most easily written down in terms of classical field theory Even although classical, such a theory leads to some quantum properties of the system. If now the discrete mass points were described by **quantum mechanics** and then the limit of a continuous medium were considered, the displacement and velocity of the string at any point would appear as operators obeying certain commutation rules. Although this last procedure is quite unnecessary for a macroscopic string, it is important for a particle or electromagnetic field. The operators specifying the field are then found to describe the elementary processes of creation and annihilation of particles or photons. The effects of such processes in intermediate states then lead to small **radiative corrections** to the consequences of the corresponding classical field theory.

FIELD THEORIES, UNIFIED. In the strict sense, this term refers to any theory which unites two or more physical theories, the unification leading to predictions that could not be deduced from either theory alone.

Thus Maxwell's electromagnetism is a unified field theory of the electric and magnetic fields. Usually, however, the term is applied to attempts to unify Maxwell's theory with general relativity theory (see **relativity theory, general**). In the same way that Newtonian mechanics indicates that by no mechanical laboratory experiment could the uniform motion of the laboratory be detected, special relativity theory (see **relativity theory, special**) indicates that by no optical laboratory experiment could such uniform motion be detected, and general relativity theory shows that by no mechanical experiment could even accelerated motion be detected, so unified field theories are essentially based on the idea that by no laboratory experiment of any kind could any motion of the laboratory be detected. Attempts to develop this (see **Kaluza theory; field theories, projective; field theory, Weyl unified; Einstein unified field theory**) have so far failed to produce a single new prediction that may be compared with the results of observation

For unified field theories of a different type, see **Born-Infeld theory, neutrino theory of light.**

FIELD THEORY, WEYL UNIFIED. Theory of gravitation and electromagnetism based on a non-Riemannian geometry in which the length of a vector may change under parallel displacement.

$$\frac{\partial l}{l} = A_\mu dx^\mu$$

The A_μ are interpreted as the electromagnetic potentials. With this interpretation, multiplying a length as (r,t) by exp $[X(r,t)]$ leads to the gauge transformation

$$A_\mu' = A_\mu + \partial_\mu X.$$

(See **gauge invariance, second kind.**)

FIELDISTOR. A **transistor** which utilizes an external electric field for the control of mobile **carriers** in the **semiconductors.**

FIFTH ORDER THEORY. More complicated corrections to lens design in which the first three terms of the expansion

$$\sin\theta = \theta - \frac{\theta^3}{3!} + \frac{\theta^5}{5!} - \frac{\theta^7}{7!} + \cdots$$

are used. In general, fifth order theory is largely replaced by the more useful methods of ray tracing.

FIGURE OF MERIT. (1) General term for various graphical relationships which summarizes certain desirable features of amplifying devices (see **gain-bandwidth product; gain margin; phase margin; mu criterion**). For a **magnetic amplifier,** the figure of merit has been defined specifically as the ratio of **power amplification** of a given control winding to the response time of the magnetic amplifier, under specified control circuit conditions. (2) The current required to produce one division deflection (usually 1 mm on a scale at a distance of 1 m) of a galvanometer. (3) Any quantity which expresses quantitatively the performance of a measuring device.

FILAMENT. The resistive element in a **thermionic tube** through which current is passed to provide the temperature required for **thermionic emission.** The surface of the filament may supply the emission, or the filament may be employed as a **heater** for an **indirectly-heated cathode.**

FILAMENT CURRENT. Current supplied to a **filament** to heat it.

FILAMENT LAMP. See **lamp, filament.**

FILAMENT NOISE. In a semiconducting filament (see **semiconductor**), **noise voltage** is observed whose frequency spectrum is similar to that of **contact noise.** It is attributed to the random production of **holes** at certain regions on the surface of the filament.

FILAMENT VOLTAGE. The voltage between the terminals of a **filament.**

FILAR MICROMETER. An instrument for measuring distances in the field of an **eyepiece.** It consists of two parallel wires, one of which is fixed and the other capable of motion in the direction perpendicular to its length by means of an accurately cut screw. The pitch of the screw is carefully determined for various temperature conditions and the head of the screw is graduated so that whole revolutions and fractions thereof may be read.

FILLED BAND. An **energy band** in which every level is occupied by an electron.

FILM. (1) Any thin sheet of material used for covering, coating or wrapping, or any thin

layer that enters into the structure, usually on or near the surface, of a substance or object. (2) The **monomolecular layer** which is formed on the surface of a solution or at an **interface** between two immiscible liquids. The **adsorption** is of such a nature that the free surface energy is a minimum. Insoluble and nonvolatile substances placed on the surface of a liquid such as water may also under certain conditions spread out on the water surface to give a monomolecular film. Adsorbed films of gases or liquids are also formed on solids such as mica, sodium chloride, glass and metals. In some cases, such as the adsorption of vapors on solids at relatively high pressures, it seems that the films may be thicker than one molecular layer and may attain thicknesses of three or four molecules. (See also **film theory**.)

FILM CONCEPT. The hypothesis that there exists, at surfaces of contact between solids and fluids (liquids or gases), a relatively slowly moving film of the fluid, which decreases in thickness with increasing velocity, parallel to the surface of the main body of fluid.

FILM, CONDENSED. A surface **film** in which the molecules are closely packed and steeply oriented to the surface. The molecular packing approaches that observed in the **crystalline state**.

FILM, EXPANDED. A state of **film** intermediate in area and other properties between gaseous and condensed films. (See **film, gaseous** and **film, condensed.**)

FILM, GASEOUS. In the gaseous **film** the molecules move about independently on the surface and their lateral **adhesion** for each other is very small. At low surface pressures (π) and large areas (A) a gaseous film obeys the relation $\pi A = kT$. At higher pressures an equation of the form $(\pi A - A_0) = xkT$ holds, where x is a constant.

FILM, LIQUID EXPANDED. See **film, expanded.** The liquid-expanded film occupies a much larger area than a condensed film but is still a coherent film. It can form a separate phase from a gaseous film with which it is in equilibrium, and obeys the relation

$$(\pi - \pi_0)(A - A_0) = C$$

where π is the surface pressure, A the surface area, and A_0 the co-area of the molecule.

FILM, MOLECULAR. A **monomolecular layer,** i.e., a **film** of a substance, produced on the surface of a liquid or solid by **adsorption** or by other means, that has a thickness of the order of molecular dimensions.

FILM THEORY OR BOUNDARY LAYER THEORY. The film theory as applied to heat or mass transfer has to do with the analysis of the physical way in which material or heat is transferred across a phase boundary where one or both of the phases may be flowing fluids. Examples of such a transfer would be heat flowing from a pipe to water moving inside, or water vapor passing from a wet surface into an air stream flowing over it. Any study of such processes must be concerned primarily with the major resistance to the flow. It is known that transfer by convection (heat) or mixing (mass) is very much faster than by conduction (heat) or diffusion (mass). If any part of the process involves conduction or diffusion, then this part will undoubtedly offer the greatest resistance to the transfer and hence will be the controlling variable.

Even though the fluid be moving past the surface in a turbulent manner, there will still be, next to the surface, a relatively stagnant *film* of the fluid. Through this film the heat or mass must pass, respectively, by conduction or by diffusion. Calculations involving transfer of heat or mass into a flowing stream are mainly concerned with the effective thickness and the properties of the film. Methods of increasing the rate of transfer are usually based on changes designed to reduce the film thickness or to change the properties of the fluid and hence increase the rate of transfer. Increasing the turbulence of the fluid tends to scrape off the film, thereby making it thinner; and raising the temperature (for liquids) lowers the viscosity of the film and makes it more easily rubbed away by the flowing fluid. Also, raising the temperature increases the rate of diffusion, and usually increases the heat conductance.

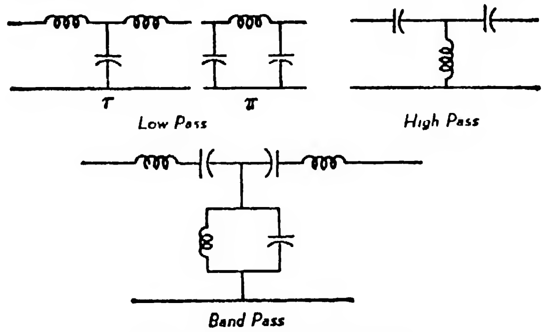
The actual film thickness is seldom known, but the way in which various factors (such as the viscosity, velocity, density, etc., of the fluid) affect it are often known, so that experimentally determined values for the rate of transfer under one set of conditions can usually be used to calculate the rate under a different set of conditions.

FILTER. An entity or device for eliminating (or reducing) certain waves or frequencies while leaving others relatively unchanged. The waves may be sound waves, or electromagnetic waves in the electrical or communications region (see **filter, wave** and derived terms) or they may be waves in the optical region. (See **filter, light.**)

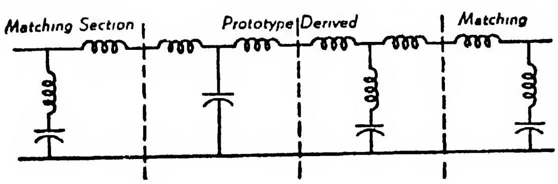
FILTER, ACOUSTIC. See **filter, wave.**

FILTER, BAND-ELIMINATION. A wave **filter** whose **transducer gain** is very low over a certain band of frequencies.

FILTER, BAND-PASS. A **wave filter** whose **transducer gain** is near unity for a certain band of frequencies, but falls to low values at frequencies above and below this band.



Some typical filter circuits



Composite low-pass filter

FILTER, CAPACITOR-INPUT. A power-supply **wave filter** in which a shunt capacitor (see **capacitor, shunt**) is the first element after the **rectifier.**

FILTER, CAVITY-COUPLED. A wave **filter** consisting of two identical chambers coupled by a third chamber.

FILTER, CHOKE-INPUT. A power-supply **wave filter** in which the first filter-element is a series **choke.** For best operation the magnitude of the inductance (henries) must be made larger than the magnitude of the load resistance (ohms) divided by 1100.

FILTER, CHRISTIANSEN. A solid-in-liquid suspension used to pass a narrow region of the spectrum while scattering all other regions. In general the indices of refraction of liquids change more rapidly with wavelength (and with temperature) than do the indices of solids. Hence a solid and a liquid may have the same index at one wavelength—which will pass freely through the suspension—while differing at all other wavelengths—which will be scattered by the suspension. Close temperature control is necessary, and the wavelength passed may be shifted appreciably by changing the temperature of the filter.

FILTER, CLICK. A **wave filter** designed to suppress key clicks.

FILTER, COLOR. An apparatus or material capable of absorbing certain wavelengths of light and transmitting others.

FILTER, COMB. A **wave filter** whose frequency spectrum consists of a number of equispaced elements resembling the tines of a comb.

FILTER, COMPOSITE WAVE. A selective **transducer** comprising a combination of two or more filters which may be of the low-pass, high-pass, band-pass, or band-elimination type.

FILTER, DECOUPLING. In most multistage **amplifiers** there are certain circuits, such as voltage supplies, etc., common to more than one stage. Since these common circuits provide a path through which energy may be fed from the output back into the input of some stages, serious feedback problems would result if something were not done to prevent them. The usual remedy is to insert a **wave filter** in those plate and grid leads which connect to points common to other plate or grid leads. These filters are frequently resistances in series with the lead and a **by-pass** condenser from the plate or grid side of the resistor to ground. The resistance used must be low enough not to cause a serious drop of voltage and the condenser should have a reactance which is low compared with the resistance at the lowest frequency for which the circuit is designed. Where the resistance would produce too much d-c voltage drop or where it does not give enough filtering action, an inductance is sometimes used. For still more

effective filtering a second resistance and condenser in cascade may be used.

FILTER, FREQUENCY. A wave filter (see **filter, wave**) designed to select or pass certain bands of frequencies with low **attenuation,** and cause very high attenuation to other frequencies. They are among the most important components of most communications systems. In the common radio receiver, filters are used to smooth out the pulsating direct current from the **rectifier** to give a steady output of the power supply. Telephone carrier circuits are possible because of filters which are used to separate the various channels, and route the signals to the proper paths. The ordinary tuned or resonant circuit might be regarded as a special form of filter, but is not commonly considered as such, since it does not have a flat pass-band.

FILTER, HIGH-PASS. A wave filter (see **filter, wave**) having a single transmission band extending from some critical or **cutoff frequency**, not zero, up to infinite frequency.

FILTER, INTERFERENCE. A filter (see **filter, light**) which modifies the spectral composition of radiant energy partly by its **interference** effects. Such filters are often constructed of thin layers of metals and **dielectrics,** and can provide narrow **pass-bands** and high **transmittances.** However, unless composed of many layers of material, an interference filter will have many transmission or reflection maxima.

FILTER, LIGHT. A device which modifies the spectral composition of radiant energy by selective absorption or reflection.

FILTER, LOW-PASS. A wave filter (see **filter, wave**) having a single transmission band extending from zero frequency up to some critical or **cutoff frequency**, not infinite.

FILTER, LUMPED IMPEDANCE THEORY OF ACOUSTIC. A theory of acoustic filtration in which it is assumed that the various components of the filter (see **filter, wave**) can be treated as separate or lumped elements, in each section of which the medium moves as a whole. Application of the theory is limited to filters the dimensions of whose components are small compared with the wavelength of the sound.

FILTER, MICROWAVE. A **wave filter** to be used at microwave frequencies. It is generally made up of distributed parameters.

FILTER, MID-BRANCH POINTS. The connection points between identical sections of a Π-section filter. (See **filter, Π-section.**)

FILTER, MID-BRANCH SECTION. A single section of a Π-section filter. (See **filter, Π-section.**)

FILTER, MID-SERIES POINTS. The connection points between identical sections of a T-section filter. (See **filter, T-section.**)

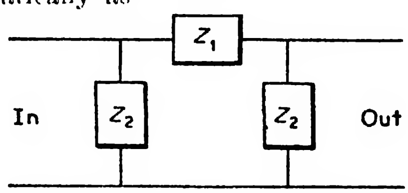
FILTER, MID-SERIES SECTION. A single section of a T-section filter. (See **filter, T-section.**)

FILTER, MODE. See **mode filter.**

FILTER, NEUTRAL DENSITY. See **neutral-density filter.**

FILTER, PARALLELED-RESONATOR. A band-pass filter (see **filter, band-pass**) in which output and input **waveguides** are coupled together through several **resonators.** The resonators are resonant, coaxial lines with a center tuning-screw for alignment purposes. The coaxial resonators are coupled to the input and output guides by means of screws, which distort the field in the main guides. The phase of the coupling depends upon whether the screw is inserted into the bottom or the top of the waveguide. The coaxial resonators are placed a guide half-wavelength apart, so that they are effectively in parallel. The ends of the main guides are short-circuited a guide quarter-wavelength past the last resonator, so that the resonators are at a high-voltage position along the main guides.

FILTER, Π-SECTION (PI-SECTION). A wave filter, one section of which can be drawn schematically as

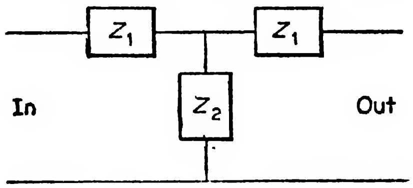


Pi-section filter

FILTER, RESISTANCE-CAPACITANCE. A circuit sometimes used to lower the ripple con-

tent of a rectifier power supply. In its simplest form it consists of a series resistor, followed by a shunt capacitor.

FILTER, T-SECTION. A wave filter, one section of which can be drawn schematically as



T-section filter

FILTER, TRANSFORMER. See **transformer filter.**

FILTER, WAVE. A **transducer** or **network** for separating waves on the basis of their frequency. It introduces relatively small **insertion loss** to waves in one or more frequency bands, and relatively large insertion loss to waves of other frequencies.

FILTER, WAVEGUIDE. A **wave filter** employing appropriately-modified waveguide sections to produce a desired, band-pass characteristic.

FINE CHROMINANCE PRIMARY. The color television signal which has frequency components up to 1.5 mc to provide fine chrominance detail in the picture.

FINE STRUCTURE. In atomic spectra, the occurrence of a spectral line as a doublet, triplet, etc., due to the interaction or coupling between the orbital angular momentum and the spin angular momentum of the electrons in the emitting atoms.

FINE-STRUCTURE CONSTANT. A universal constant α evaluted by the expression:

$$\alpha = 2\pi e^2/ch$$

where e is the electronic charge, c is the velocity of light and h is the Planck constant. It has the least squares adjusted output value of $(7.29698 \pm .00005) \times 10^{-3}$.

FINE STRUCTURE OF ALPHA PARTICLE SPECTRUM. See **alpha particle spectrum.**

FIRING. (1) In a **magnetic amplifier,** the transition from the unsaturated to the saturated state of the **saturable reactor** during the conducting or gating alternation. Firing is also used as an adjective modifying phase or time to designate when the firing occurs. (2) The initiation of discharge in a **gas discharge tube.**

FIRING ANGLE. See **gate angle.**

FIRST DETECTOR. See **superheterodyne.**

FIRST ORDER THEORY. (1) Any theory which involves only the most important terms, such as the terms proportional to x in a series expansion of $f(x)$ about $x = 0$. Many physical theories are of first order. (2) (Optics) An expansion of the sine of an angle into a series in terms of the angle itself is

$$\sin\theta = \theta - \frac{\theta^3}{3!} + \frac{\theta^5}{5!} - \cdots$$

First order theory or Gauss theory neglects all but the first of these terms.

FISHBONE ANTENNA. See **antenna, fishbone.**

FISSILE. Capable of undergoing **fission.**

FISSION CHAIN OR FISSION DECAY CHAIN. The successive β-decays starting with a fission product and ending in a stable nucleus of the same mass number. For example:

$$_{54}Xe^{140} \xrightarrow{16\ s} {}_{55}Cs^{140} \xrightarrow{66\ s} {}_{56}Ba^{140} \xrightarrow{12.8\ d} {}_{57}La^{140} \xrightarrow{40\ h} {}_{58}Ce^{140} \text{ (stable).}$$

FISSION CHAMBER. A device for the detection of slow neutrons in which the wall of an **ionization chamber** is lined with a thin layer of uranium. A slow **neutron** will cause a fission in the uranium, and the highly ionizing fission fragments are detected in the chamber.

FISSION, DEFORMATION ENERGY OF. In the liquid-drop model of **fission** the deformation energy is the energy required to deform the nucleus from a spherical shape to an ellipsoid. If ϵ is a parameter representing the degree of deformation, the deformation energy is given by:

$$\text{deformation energy} = \epsilon^2\left(5.2A^{2/3} - 0.117\frac{Z^2}{A^{1/3}}\right)$$

when the deformation energy is zero, or negative, the spherical nucleus will deform and, consequently, undergo fission spontaneously.

The condition for spontaneous fission is, therefore:

$$\frac{Z^2}{A} > 45.$$

FISSION EXPECTATION, ITERATED. See **iterated fission expectation.**

FISSION NEUTRONS. Neutrons emitted as the result of nuclear fission. (See **fission, nuclear.**) They are characterized by a continuous spectral distribution with a maximum at about 10^6 ev, and that extends to higher energies according to the expression

$$\sinh \sqrt{2E} \exp(-E).$$

FISSION NEUTRONS, DELAYED. Delayed neutrons emitted by the products of a nuclear fission. (See **neutrons, delayed.**)

FISSION NEUTRONS, PROMPT. Neutrons emitted during a nuclear fission. (See **fission, nuclear.**)

FISSION, NUCLEAR. The division of a heavy nucleus into two approximately equal parts. Nuclear fission reactions are distinguished from **spallation** in which relatively smaller fragments are ejected, leaving behind only one large residual nucleus. Nuclear fission of such nuclides as U^{235}, U^{233}, Pu^{239}, which follow the capture of slow neutrons, release large quantities of energy. Fission can also be induced by charged particles and photons. (When induced by photons, it is called photofission.)

FISSION, PHOTO-. Nuclear fission induced by photons. (See **fission, nuclear.**)

FISSION PRODUCTS. The radioactive nuclei formed in the fission process. They exhibit a wide range of **atomic numbers, atomic masses, half-lives, decay energies,** etc.

FISSION PRODUCT POISONING PROCESS. When a nuclear **reactor** operates, certain nuclei with larger cross sections for the capture of thermal neutrons are produced, either as direct fission products or from the decay of the latter. These act as "poisons" in the reactor. (See **poison.**)

FISSION SPECTRUM. The distribution in energy of the neutrons arising from fission. (See **fission neutrons.**)

FISSION, SPONTANEOUS. Nuclear fission which takes place without particles or photons entering the nucleus from outside. The half-lives for decay by this process, which is exhibited by only the heaviest elements, are very long.

FISSION, TERNARY. The division of a nucleus into three parts. There is question as to whether this term should be applied to the frequently-observed type of fission wherein a small, charged nuclear fragment, such as a proton, α-particle, triton, etc., is emitted during the process of splitting into two large fragments, or whether the term should be reserved for the phenomenon of splitting into three massive fragments, a process which has not been conclusively observed.

FISSION YIELD. The fraction of **fissions,** usually expressed as a percentage, that gives rise to a specified nuclide or a group of isobars. Since there are two products per fission, the total of all fission yields for a given fission process is 200 per cent. The **fission yield curve** is different for each mode of induced fission.

FISSION YIELD, CHAIN. For a particular **mass number,** the sum of the independent fission yields of all the **isobars** having that mass number.

FISSION YIELD CURVE. The characteristic fission yield curve (yield vs. mass number) is of the so-called "double-hump" shape. In the case of U^{235} the two broad peaks are at masses 85–104 and 130–149, showing the prevalence of asymmetric fission. There is a "trough" between them in the mass region corresponding to symmetric fission whose yield is of the order of 0.1 per cent of the most probable asymmetric yields.

FISSION YIELD, INDEPENDENT. The percentage of **fissions** giving rise to a particular fission product nuclide only by direct formation from fission, not by decay from earlier members of its fission chain. Also called primary fission yield. (See **fission yield.**)

FISSIONABLE. Capable of undergoing nuclear fission. (See **fission, nuclear.**)

FITZGERALD FACTOR. The quantity

$$\left(1 - \frac{v^2}{c^2}\right)^{½}$$

originally appearing in the **Fitzgerald-Lorentz contraction hypothesis.** Now used with v denoting the relative velocity of two systems.

FITZGERALD-LORENTZ CONTRACTION HYPOTHESIS. Hypothesis proposed by Fitzgerald in 1893 to account for the null result of the **Michelson-Morley experiment,** that in moving through the **ether** with velocity v a body contracted in the direction of such motion in the ratio

$$\left(1 - \frac{v^2}{c^2}\right)^{½} : 1.$$

Applied in 1895 to the **Lorentz theory of the electron.** The special relativity theory (see **relativity theory, special**) yields the same contraction, but ascribes it to the relative motion of the body and the observer rather than to the motion of the body through the ether.

FIXATION. (1) The process of removing silver halides remaining in photographic emulsions after development. Fixation is most commonly accomplished by bathing the emulsion in sodium thiosulfate solution ("hypo"). (2) The concentration of the eye on an established point, i.e., the maintenance of the eye in such a position that the image of the point falls in the center of the **fovea.**

FIXED-FREQUENCY TRANSMITTER. See **transmitter, fixed-frequency.**

FIXED-POINT SYSTEM. A system of number notation in which a number is represented by a single set of digits, and in which the position of the **radix point** is not numerically expressed. (See also **floating-point system.**)

FIXED TRANSMITTER. See **transmitter, fixed.**

FIZEAU EXPERIMENT. Confirmation of the conclusion of the **ether-drag hypothesis** that the velocity of light increases by an amount

$$v\left(1 - \frac{1}{n^2}\right)$$

when moving through a medium, of refractive index n, which itself is moving with velocity v. A beam of light was divided into two parts which were sent in opposite directions through two tubes filled with flowing water, and interference fringes were observed as a function of the velocity of the water. The result is also a consequence of special relativity theory. (See **relativity theory, special.**)

FIZEAU TOOTHED WHEEL. Fizeau measured the velocity of light by passing a beam through a rapidly-rotating, toothed wheel to a distant mirror, and returning the light through the same wheel. At low speeds the light returned through the same opening that it had started through. At higher speeds, no light could get back through the wheel since the wheel had advanced by one-half the distance from the center of one tooth to the center of the next tooth. At still higher wheel speeds, the returning pulse of light would pass through the next tooth opening. This type of experiment was soon replaced by a rotating mirror for experimental measurement of the velocity of light.

FLAG. (1) The small metal piece which holds the **getter** in a **vacuum tube** prior to exhaustion. (2) A light shield for a television camera

FLAGPOLE ANTENNA. See **antenna, flagpole.**

FLAME. A reaction or reaction-product, partly or entirely gaseous, which yields heat and more or less light, as the result of a chemical reaction, commonly oxidation.

FLAME, LUMINOUS. A pale or bright colored flame, as a candle flame or a sodium light. This term is also applied to the inner cone or reducing portion of the **Bunsen flame,** and to the inner parts of other gas flames that show two portions.

FLAME, NONLUMINOUS. A flame that is dark in color, and of little brightness; or the oxidizing or outer part of the Bunsen flame, and outer parts of other gas flames that show two portions.

FLANGE, CHOKE. A low-loss, **waveguide coupling.** It consists of a half-wavelength, low-impedance line inserted in series with the **waveguide** at the joint.

FLASH ARC. The sudden, sometimes destructive, increase in emission of a **thermionic**

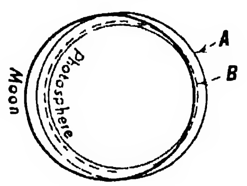
cathode thought to be due to irregularities in the cathode surface.

FLASHBACK VOLTAGE. The peak inverse voltage at which ionization occurs in a **gas-tube.**

FLASH POINT. The lowest temperature at which a substance will decompose to an inflammable gaseous mixture, demonstrable through its explosive quality.

FLASHOMETER. A device for studying the time-intensity distribution of flashes of light.

FLASH SPECTRUM. At the instant of second or third contact during a total solar **eclipse** the edge of the moon is tangent to the **photosphere** of the sun as shown in the figure.



With the photosphere (B) covered, the highly heated atmosphere of the sun, known as the **reversing layer** and the **chromosphere** (A), flashes into view. With the photosphere covered the continuous spectrum of the sun is cut off and the bright-line **spectrum** radiated by the atmosphere may be observed.

FLAT SPACE-TIME. Space-time for which the **Riemann-Christoffel tensor** vanishes. The **metric** can then always be chosen thus

$$g_{\mu\nu} = \delta_{\mu\nu}, \text{ if } x_4 = ict.$$

F LBF S SYSTEM OF UNITS. Any system of units based on the choice of the foot, the pound force and the second as fundamental quantities. (See **Introduction.**)

FLEMING VALVE. An early **thermionic diode** used as a **detector.**

FLETCHER-MUNSON CONTOURS. Equal **loudness** curves for pure tones (see **tone, simple**), plotted as contours on a sound pressure–sound frequency graph.

FLEXION-POINT EMISSION CURRENT. That value of current on the **diode characteristic** for which the second derivative of the current with respect to the voltage has its maximum negative value. This current corresponds to the upper flexion point of the diode characteristic, and is an approximate measure of the temperature-limited emission current.

FLEXURAL WAVE. See **wave, flexural.**

FLEXURE. A term which is used to denote the curved or bent state of a loaded beam. A horizontally located **beam,** transversely loaded with vertically directed load, offers an example of load-carrying ability derived through flexure. In flexure, an elastic structural material undergoes a deflection sufficient to set up in its material stresses which will support the load. Deflection under load is an essential and necessary part of the process of load carrying by a beam, for until the deflection has occurred, there are set up in the beam no resisting forces. Thus if an unloaded beam is perfectly straight and horizontal, it must assume a slightly curved position if any external load is supported by it. The only way in which a loaded beam could be straight would be to have had an initial deflection in a direction opposite to the loading.

FLICKER. The sensation produced by a fluctuation in brightness at a rate comparable to the reciprocal of the period of persistence of vision.

FLICKER EFFECT. Minute variations in the cathode current of **thermionic** vacuum **tubes** which may be caused by random changes in cathode activity or positive ion emission.

FLICKER PHOTOMETER HEAD. A **bench photometer** head in which, by means of a rotating sector-disk, the two illuminations to be compared are presented to the observer in rapid alternation (but not too rapid), any difference between them being detected as a noticeable **flicker.** This type of photometer is especially useful when the sources are not of exactly the same color.

FLIP-FLOP CIRCUIT. (1) An **Eccles-Jordan circuit** or **bistable multivibrator.** (2) The use of this term in color television, for **color-phase alternation,** should be avoided.

FLOATING BODY, STABLE EQUILIBRIUM OF. See **stable equilibrium of floating body.**

FLOATING BODY, UNSTABLE EQUILIBRIUM OF. See **unstable equilibrium of floating body.**

FLOATING-POINT SYSTEM. A system of number notation in which two sets of digits are used, the added set being included to denote the location of the **radix point.** (See also **fixed-point system.**)

FLOATING POTENTIAL. The d-c potential which appears at an open-circuit electrode when normal d-c potentials are applied to all other electrodes.

FLOOD PROJECTION. A method of **facsimile pick-up** which utilizes a completely illuminated subject. **Scanning** is achieved by an aperture which moves between the subject and light-sensitive, pick-up device.

FLOP-OVER CIRCUIT. Colloquialism for **bistable multivibrator** or **trigger circuit.**

FLOQUET THEOREM. Given a **linear differential equation** with periodic coefficients that are one-valued functions of the independent variable, such as **Mathieu's equation,** then there exists a solution of the form $y = e^{\mu x}P(x)$, where $P(x)$ is a periodic function and μ is a constant The **general solution** of the differential equation is $y = Ae^{\mu x}P(x) + Be^{-\mu x}P(-x)$, where the constants of integration are A and B.

FLOW CURVE. A graphical representation of the flow of a fluid. It may take the form of a graph of total shear against time, which would be linear for a Newtonian fluid (see **fluid, Newtonian**), but has a more complex shape for a thixotropic fluid (see **fluid, thixotropic**).

FLOW DIAGRAM. A graphical representation of a sequence of operations.

FLOW, LAMINAR. Flow in which sheets (or *lamina*) of fluid slide steadily over one another, as in streamline flow. (See **flow, streamline.**)

FLOW, MEASUREMENT OF. For measurements of total flow along a pipe or channel, various sorts of **flow meter** are used. For measuring the flow velocity at a point, some form of **anemometer** is required. The most common is a **Pitot-static** tube, although hot wires, vane anemometers, pressure plates and many other methods have been used.

FLOW METER. An instrument for measuring rate of flow, that is, the volume flow along a pipe or channel. Examples are the **Venturi meter,** the **orifice plate, weirs** of various forms and displacement meters.

FLOW OF A FLUID. The nature of fluid flow depends on the physical properties of the fluid substance. The most simple behavior is shown by frictionless fluids, particularly in irrotational motion, but a considerable amount is known of the flow of Newtonian fluids (see **fluid, Newtonian**) in which the shear stress is proportional to the rate of strain. The flow of more complex fluids, e.g., Maxwellian and thixotropic fluids, presents problems of great difficulty. (See **fluid, Maxwellian,** and **fluid, thixotropic.**)

FLOW, ROTATIONAL. Flow in which the **vorticity** is appreciable and no velocity potential function can be set up. Classes of rotational flow are the slow motion of a viscous fluid, motion of rotating fluids and turbulent motion.

FLOW, SECONDARY. The flow in pipes and channels is frequently found to possess components at right angles to the axis. These components which take the form of diffuse vortices with axes parallel to the main flow form the secondary flow. Three types may be mentioned: (i) Secondary flow in curved pipes or channels, being a motion outwards near the flow center and inwards near the walls. (ii) Secondary flow in straight pipes and channels of non-circular section, being a motion along the walls toward corners or places of large curvature and from there to the center of the flow. This only occurs in turbulent flow (see **flow, turbulent**). (iii) Secondary flow in pulsating flow. This is due to second order effects and is particularly striking with **ultrasonic waves.**

FLOW, SEPARATION OF. The flow of a slightly viscous fluid past a solid body closely resembles that of an inviscid fluid so long as the thin layer of retarded fluid near the wall is not brought to rest by the pressure gradients of the flow. If it is brought to rest, the whole flow separates from the surface and the direction of flow is reversed downstream of the position of flow separation.

FLOW, STEADY. Flow in which the flow velocity at a point fixed with respect to the coordinates is independent of time. If the flow is turbulent, a flow in which the mean values are independent of time. Many com-

mon flows may be made steady by a suitable choice of the coordinates.

FLOW, STREAMLINE. Flow in which fluid particles move along the streamlines. This motion is characteristic of viscous flow at low **Reynolds numbers** or of inviscid, irrotational flow. (See also **flow, laminar;** and **flow, rotational.**)

FLOW, TURBULENT. Flow in which the fluid velocity at a fixed point fluctuates with time in a nearly random way. The motion is essentially rotational, and is characterized by rates of momentum and mass transfer considerably larger than in the corresponding laminar flow. (See **flow, laminar.**)

FLOW, UNIFORM. Flow steady in time, *or* flow which is the same at all points in space.

FLOWING JUNCTION. A method of setting up a junction between two **electrolytes** which has important advantages for use in electrochemical measurements, especially of **electrode potential.** In its simplest form, this arrangement consists of an upward current of the heavier electrolyte meeting a downward current of the other at a point where a horizontal outlet tube joins the vertical tube through which the liquids enter

FLUCTUATION NOISE. Random noise which has a uniform energy versus frequency distribution. Examples are **thermal noise** and **shot noise.**

FLUID. A state of matter in which only a uniform isotropic pressure can be supported without indefinite distortion; so, a gas or a liquid. The distinction between highly viscous liquids and solids is a difficult one, the same material acting as an ordinary liquid under some circumstances and as a solid under others.

FLUID, CONVERGENCE OF. The local accumulation of fluid accompanying a negative **divergence** of the flow velocity.

FLUID DENSITY. The mass per unit volume of fluid, measured in gm cm^{-3}, lb in.$^{-3}$ or lb ft^{-3}. It may be measured using **areometric methods,** floating hydrometers, specific gravity bottles, etc.

FLUID, DIVERGENCE OF. The rate of decrease of the fluid density ρ is given by the **equation of continuity,**

$$\frac{\partial \rho}{\partial t} + \operatorname{div}(\rho \mathbf{u}) = 0$$

where $\mathbf{u}$ is the flow velocity. A divergence of the mass flow $\rho\mathbf{u}$ implies that the density is decreasing.

FLUID DYNAMICS. The study of the motion of Newtonian fluids (see **fluid, Newtonian**), including viscid and inviscid, compressible and incompressible flow together with the phenomena associated with free surfaces and buoyancy forces caused by gravitational fields. The phrase carries the implication that the study is carried out from the physical standpoint rather than the standpoint of practical engineering.

FLUID, ELASTIC. A fluid for which elastic stresses and hydrostatic pressures are large compared with viscous stresses.

FLUID EQUATION OF CONTINUITY. See **continuity equation.**

FLUID EQUATION OF MOTION. In the Eulerian description of fluid motion, the equation of motion is, in tensor notation,

$$\rho \frac{\partial u_i}{\partial t} + \rho u_j \frac{\partial u_i}{\partial x_j} = \frac{\partial p_{ij}}{\partial x_j} + F_i$$

where u_i is the fluid velocity at position x_i and time t, ρ is the fluid density, p_{ij} is the stress in the Ox_i direction transmitted across an area with normal parallel to Ox_j, F_i is the external force acting.

In the Lagrangian description, it is

$$\frac{du_i}{dt} = \frac{\partial p_{ij}}{\partial x_j} + F_i$$

where u_i is now the velocity of a fluid particle which at time t_0 was at the position ${}_0x_i$.

FLUID EQUIPOTENTIAL SURFACE. A surface on which the velocity potential of the motion has a constant value, and consequently one everywhere at right angles to the flow, *or,* in hydrostatics, a surface of constant gravitational potential and consequently a surface of constant pressure.

FLUID FLOW. See **flow of a fluid.**

FLUID FLOW STAGNATION POINT. See **stagnation point, fluid flow.**

FLUID FRICTION. The stresses which are set up in a **fluid** when it is distorted and which tend to convert the mechanical energy of the system to heat. Many simple liquids and most gases under ordinary conditions exhibit Newtonian viscosity, but suspensions and highly viscous liquids have more complicated responses to distortion.

FLUID HOMOGENEOUS. A **fluid** whose properties are the same at all points.

FLUID, INCOMPRESSIBLE. A **fluid** whose density is substantially unaffected by change of pressure. The behavior of a real fluid is similar to that of an incompressible fluid only if the pressure variations in the flow are small compared with the bulk **modulus of elasticity.** For a fluid in motion in a gravitational field with velocities of order v, it is necessary that both v and $\sqrt{gh}$ should be small compared with the velocity of sound in the fluid. (h is the depth of the fluid and g the acceleration due to gravity.)

FLUID, ISOTROPIC. A **fluid** whose local properties are independent of rotation of the axes of reference. A fluid may become anisotropic as a result of shearing flow, proximity to a wall or application of a strong electric field.

FLUID, MAXWELLIAN. A visco-elastic fluid in which the stress tensor p_{ij} is related to the rate of strain

$$\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)$$

by

$$p_{ij} + \tau_M\left(\frac{\partial p_{ij}}{\partial t}\right) = \eta\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)$$

where η is the fluid viscosity for steady motion, and τ_M is the relaxation time of the elastic stresses set up by a sudden deformation.

FLUID MECHANICS. The study of the mechanical properties of fluids, including **hydrostatics, hydraulics, hydrodynamics** and gas dynamics (compressible flow). It is implied that problems of practical engineering are kept in mind.

FLUID MOTION, ENERGY EQUATION FOR. The expression of the conservation of energy for fluid motion takes two forms, depending on whether the flow is represented in Eulerian or Lagrangian specification. Using the Eulerian method of analysis, the energy equation is

$$\operatorname{div}[\tfrac{1}{2}\rho(\mathbf{u}\cdot\mathbf{u})\mathbf{u} + p\mathbf{u}] + \frac{\partial}{\partial t}(\rho U) + \rho\mathbf{g}\cdot\mathbf{u} = 0$$

where ρ is the fluid density, $\mathbf{u}$ is the (vector) velocity at a fixed point in space, p is the local pressure, U is the internal energy per unit mass, $\mathbf{g}$ is the external force field.

Using the Lagrangian method, the energy equation refers to the energy of a particular mass of fluid and is essentially the Bernouilli equation. (See **Bernouilli law.**)

FLUID MOTION, IRROTATIONAL. Flow in which the **curl** of the flow velocity is everywhere zero, and so a flow that can be described by a velocity potential. If the flow is also incompressible, the velocity potential obeys the **Laplace equation** and solutions may be found by standard methods.

FLUID, NEWTONIAN. A fluid in which the viscous stresses are a multiple of the rate of distortion. The constant of proportionality is the fluid viscosity η. In symbols,

$$p_{ij} = \eta\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)$$

where p_{ij} is the viscous stress in the direction of flow, transmitted across a surface parallel to the flow. $\frac{1}{2}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)$ is the rate of strain tensor.

FLUID, PERFECT. A frictionless fluid which offers no resistance to flow except through inertial reaction.

FLUID PARTICLE. A fluid particle or material particle is a hypothetical particle that moves with the flow velocity of the fluid. Owing to molecular diffusive movement, it may not be identified with a particular molecule, but the concept is useful in discussing the flow of fluids.

FLUID, SLIP ALONG A SURFACE. See **slip of a fluid along a surface.**

FLUID, SLOW MOTION OF SPHERE IN INCOMPRESSIBLE VISCOUS. See **slow motion of sphere in incompressible viscous fluid.**

FLUID, THIXOTROPIC. A fluid whose viscosity is a function not only of the shearing stress, but also of the previous history of motion within the fluid. The viscosity usually decreases with the length of time the fluid has been in motion. Such systems commonly are concentrated solutions of substances of high molecular weight, or colloidal suspensions. (See **thixotropy.**)

FLUID VELOCITY POTENTIAL. A function of position in the flow, such that its gradient equals the fluid velocity everywhere. A velocity potential cannot be set up unless the flow is irrotational.

FLUID, VISCOUS. A fluid with an appreciable fluid friction, usually one in which the frictional stresses are described by a single Newtonian coefficient of viscosity, i.e., the stress tensor p_{ij} is related to the rate of strain tensor

$$\frac{1}{2}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)$$

by

$$p_{ij} = \eta\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)$$

where η is the fluid viscosity.

FLUID, VISCOUS, EQUATION OF MOTION OF. The equation of motion of a viscous, incompressible fluid with a Newtonian viscosity is

$$\rho\frac{\partial u_i}{\partial t} + \rho u_j\frac{\partial u_i}{\partial x_j} = -\frac{\partial p}{\partial x_i} + \eta\nabla^2 u_i$$

where u_i is the flow velocity, ρ is the fluid density, p is the hydrostatic pressure, η is the viscosity, ∇^2 is the Laplacian operator, $\dfrac{\partial^2}{\partial u_j^2}$.

If the motion is very slow, stresses due to acceleration of the fluid may be neglected in comparison with the viscous stresses, and the velocity field satisfies the equation,

$$\frac{\partial^4\psi}{\partial x_i^2 \partial x_j^2} = 0$$

where ψ is a stream (or current) function for the flow.

FLUID, VISCOUS, FLOW BETWEEN ROTATING CYLINDERS. The only practical realization of **Couette flow.** For low relative velocities of rotation of the cylinders, the flow is laminar (see **flow, laminar**) and the transmitted torque is, per unit length,

$$G = 4\pi\eta\frac{R_1^2R_2^2}{R_2^2 - R_1^2}(\Omega_2 - \Omega_1)$$

where η is the fluid **viscosity,** R_1, R_2 are the radii of the inner and outer cylinders, Ω_1, Ω_2 are the angular velocities of the inner and outer cylinders.

If the angular momentum of flow decreases outwards from the axis, i.e., if the inner cylinder only rotates, the flow becomes unstable to small disturbances at a comparatively low velocity of rotation. If the angular momentum increases outwards, the flow is stable to small disturbances and laminar flow persists to much higher velocities of rotation, and, in this form, the arrangement is suitable for the measurement of the viscosity of liquids and gases of small viscosity

FLUID, VISCOUS, STEADY FLOW THROUGH CIRCULAR PIPE. For small flow velocities, the flow of a viscous fluid through a circular pipe of radius r and length l is laminar (see **flow, laminar**), the velocity profile is parabolic and the relation between volume flow and longitudinal gradient of hydrostatic pressure is

$$\pi r^2 U_m = \frac{\pi}{8\eta}\frac{p_1 - p_2}{l}r^4$$

where $\pi r^2 U_m$ is the volume flow, η is the fluid viscosity, $(p_1 - p_2)/l$ is the pressure gradient.

The flow is laminar and steady if the **Reynolds number** of the flow, $2\rho r U_m/\eta$, is less than 2000, and then the measurement of total flow for a known head provides a convenient and accurate method of measuring viscosity.

FLUIDITY. The property of a substance that expresses its ability to flow, as contrasted with **viscosity,** which is the resistance to flow. Fluidity is a measure of the rate at which a fluid is deformed by a shearing stress, and is mathematically the reciprocal of the viscosity.

FLUIDITY, UNITS OF. The unit of fluidity in the cgs system of units is the **inverse poise,** i.e., gm^{-1} cm sec.

FLUORESCENCE. (1) The process of emission of **electromagnetic radiation** by a substance as a consequence of the absorption of energy from some other radiation, which may be either electromagnetic or particulate, provided that the emission continues only as long as the stimulus producing it is maintained. That is, fluorescence is a **luminescence** which ceases within about 10^{-8} sec after **excitation** stops; this period of time being the lifetime of an atomic state for a normal **allowed transition.** (2) The term fluorescence may also be applied to the radiation emitted, as well as to the emission process. (3) See **fluorescence, x-ray.**

FLUORESCENCE, IMPACT. See **impact fluorescence.**

FLUORESCENCE, X-RAY. In x-ray terminology, the term fluorescence may be used in the more specific sense (than given in the general definition above) to denote the characteristic x-rays (see **x-rays, characteristic**) emitted as a result of the absorption of x-rays of higher frequency.

FLUORESCENCE YIELD. The probability that an atom whose electronic structure has been excited will emit an x-ray photon, in the first transition, rather than an **Auger electron.** The value of the fluorescence yield lies between 0 and 1, characteristic of the particular state of excitation of an atom of a particular element. The K-shell fluorescence yield increases with increasing atomic number, and is the sum of the $K \rightarrow L_{II}, K \rightarrow L_{III} \cdots$ transitions.

FLUORESCENT SCREEN. A plate coated with a material readily fluorescent. It is used to observe certain patterns or other properties of invisible radiations, such as x-rays, from the fluorescent radiations emitted by the screen. It is also used to form the visible image in **cathode-ray tubes** as used in **oscilloscopes** and **television tubes.**

The distinction between fluorescent and phosphorescent screens is frequently not clearly defined. Fluorescent screens are properly those with only a very short glow-period after the exciting radiation (or electron beam) is extinguished.

FLUORINE. Gaseous element. Symbol F. Atomic number 9.

FLUOROMETER. (1) An instrument for the measurement of **fluorescence.** (2) A device for photometric measurements in the ultraviolet by means of the fluorescence produced by it.

FLUOROMETRY. Measurement of the intensity and color of fluorescent radiations.

FLUOROSCOPE. (1) An apparatus for the determination of **fluorescence** by visual comparison, by means of an optical system, with a standard. (2) A screen of fluorescent material used to transform invisible radiation (x-rays, γ-rays, etc.) to visible light.

FLUTTER. In communication practice, (1) distortion due to variations in loss resulting from the simultaneous transmission of a signal at another frequency, or (2) a similar effect due to phase distortion. (3) In recording and reproducing, the deviations in reproduced sounds from their original frequencies, which result in general from irregular motion during recording, duplication or reproduction. The colloquial term **"wow"** is defined in the same way, but is commonly applied to relatively slow variations (for example, one to five or six repetitions per second) which are recognized aurally as pitch-fluctuations, in contradistinction to the roughening of tones, which is the most noticeable effect of rapid fluctuations. A constant difference in pitch such as results from a difference in the average speeds during recording and reproduction is not included in the meanings of the terms **"wow," "flutter,"** and **"drift."** By an extension of their meanings, the terms "flutter" and "wow" are used in designate variations in speed itself or variations in recorded wavelengths. Although most recorded sound comprises multitudes of tones, it is convenient to refer to flutter as variations in frequency, assuming the recorded sound to have been a single, steady tone.

FLUTTER ECHO. See **echo, flutter.**

FLUTTER INDEX. A measure of the perceptibility of frequency modulation in a single tone. Based on data presented in an article entitled "Analysis of Sound Film Drives," by W. J. Albersheim and D. MacKenzie, *Jour. Soc. Mot. Pict. Eng.*, **37**, 453, 1941. An approximate formula for flutter index for continuous tones in a moderately live room is as follows:

$$I = \frac{\Delta fx}{r} = \frac{kfx}{100r}$$

where Δf is the rms deviation of frequency from mean in cycles, f is the frequency of tone, k is per cent rms **flutter**, I is **flutter index**, r is flutter rate, x is $\frac{1}{6}$ for rates greater than 5 cps.

For flutter rates of 1 to 5 cps, the following relations are suggested:

$$x = \frac{r}{30}$$

from which, when $f = 3000$ cps, $I = k$.

For flutter rates less than 1 cps, the following relations are suggested:

$$x = \frac{r^2}{30}$$

from which, when $f = 3000$ cps, $I = kr$.

For the general case, wherein $x = \frac{1}{6}$, the flutter index, when multiplied by $6\sqrt{2}$, is the argument of the **Bessel functions** of the first kind, and the coefficients of the various orders of the Bessel functions have been shown to represent the amplitudes of the corresponding orders of the side-frequencies present in a frequency-modulated tone.

For flutter rates above 5 cps, the ear apparently hears the side-frequencies as extraneous effects, and therefore will perceive approximately the minimum-flutter at the same value of flutter index over a wide range of signal-frequencies, percentages of flutter, and rates (assuming relatively constant acoustic conditions). For flutter rates less than 5 cps, the ear apparently distinguishes the time-frequency variation rather than the discrete side-frequencies, and so the expression which describes the phenomena becomes more complicated. The flutter index of any given device having a constant per cent flutter will vary with the signal-frequency so that the test-frequency should always be stated, the flutter index will be assumed to refer to a standard test tone of 3000 cycles per second.

FLUTTER, PER CENT. The per cent flutter in a reproduced tone is the root-mean-square deviation from the average frequency, expressed as a percentage of average frequency.

FLUTTER, PER CENT TOTAL. Per cent total flutter is the value of flutter indicated by an instrument which responds uniformly to flutter of all rates from 0.5 up to 200 cycles per second. Except for the most critical tests, instruments which respond uniformly to flutter of all rates up to 120 cycles per second are adequate, and their indications may be accepted as showing per cent total flutter.

FLUTTER RATE. The number of frequency-excursions in cycles per second, in a tone which is **frequency-modulated** by **flutter.** Each cyclical variation is a complete cycle of deviation, for example, from maximum-frequency to minimum-frequency and back to maximum-frequency at the rate indicated. If the overall flutter is the resultant of several components having different repetition rates, the rates and magnitudes of the individual components are of primary importance. (See **flutter index.**)

FLUX. (1) A quantity proportional to the surface integral of the normal (perpendicular) force field intensity over a given area.

$$\text{Flux} = K \int_s F_N dS$$

where F_N is the normal component of a **field,** (e.g., gravitational, electric, magnetic), and K is the constant of proportionality between the field and the flux density (**permittivity, permeability,** etc.). (See also **electric flux density; magnetic flux density.**) (2) A term which denotes the volume or mass of fluid or particles transferred across a given area perpendicular to the direction of flow in a given time.

There are many specific applications in physics of the term flux. For electromagnetic radiation, it signifies the energy per unit time, or the power passing through a surface. For photons or particles, flux is the number per unit time passing through a surface. In nuclear physics, flux commonly means the product nv, where n is the number of particles per unit volume and v is their mean velocity.

FLUX-AMPERE-TURN LOOP. See **dynamic hysteresis loop.**

FLUX-CURRENT LOOP. See **dynamic hysteresis loop.**

FLUX, ELECTRIC. The flux of a general vector field through a given surface is proportional to the surface integral of the normal

component of the field. This concept is useful primarily because the flux through a closed surface, due to an inverse square law field, depends only upon the sources enclosed by the surface, and not upon the size or shape of the enclosing surface. (See **field, electric; electric flux density**; and **induction, electric.**)

FLUX EXCLUSION. See **Meissner effect.**

FLUX, GRAVITATIONAL. The surface integral of the normal component of the gravitational field over a given area or the product of that integral by the inverse of the **gravitation constant.** (See **flux.**)

FLUX GUIDE. In **induction-heating** usage, magnetic material to guide **electromagnetic flux** in desired paths. The guides may be used either to direct flux to preferred locations or to prevent the flux from spreading beyond definite regions.

FLUX LINKAGE. Since **magnetic induction (flux density)** is solenoidal

$$(\nabla \cdot \mathbf{B} = 0),$$

any closed contour links a definite amount of flux. This flux linkage

$$\phi = \int \mathbf{B} \cdot d\mathbf{S}$$

plays an important role in the basic relations of electromagnetism.

FLUX, LUMINOUS. The time rate of flow of **luminous energy** or the radiant flux (see **flux, radiant**) evaluated by means of the standard **luminosity function.**

FLUX, MAGNETIC. See **magnetic flux.**

FLUX OF DISPLACEMENT. See **induction, electric.**

FLUX, RADIANT. The time rate of transfer of radiant energy. (See **energy, radiant.**)

FLUX REFRACTION. When a ferromagnetic body composed of two pieces of different magnetic **permeability** is placed in a magnetic field, or when a **dielectric** composed of two adjacent portions of different dielectric constant is placed in an electric field, the lines of magnetic induction in the former case, and the lines of electric displacement in the latter, if oblique to the interface, abruptly change their direction. The phenomenon is thus somewhat analogous to the **refraction** of light. But the law is different. Whereas, in the case of light the ratio of the sines of the angles of incidence and refraction is constant, in the case of flux refraction it is the ratio of the tangents of the angles that is constant.

For an electric current flowing across a boundary between two conductors of different electrical resistivity, there is a refraction of the lines of flow, likewise obeying the tangent law.

FLY-BACK. (1) The shorter of the two intervals of time which comprise a sawtooth wave. (See **wave, sawtooth.**) (2) The retrace motion of an electron-beam, as, for example, in a picture tube.

FLYWHEEL. A heavy wheel with a large **moment of inertia** (generally obtained by concentrating most of the mass on the rim) such that small fluctuations in the **torque** do not affect the uniformity of the motion appreciably.

FLYWHEEL DAMPER. See **free-wheeling diode.**

FLYWHEEL EFFECT. The ability of a **resonant circuit,** because of its energy storage, to operate continuously from short pulses of energy of constant frequency and phase.

FLYWHEEL SYNCHRONIZATION. The synchronization of a **sinusoidal oscillator** with the use of pulses of constant phase and frequency.

FOCAL COLLIMATOR. A type of **collimator** consisting of an **objective lens** at one end of a tube, and a pair of cross hairs placed accurately in its **focal plane** at the other end.

FOCAL ISOLATION. The **focal length** of an ordinary single lens is greater for longer wavelengths. By placing a screen with a pinhole at the proper distance from a simple crystal-quartz lens, long wavelength infrared radiation focused on the pinhole will pass through, while very little of other wavelengths not focused on the hole will pass through and these can be further eliminated by a small screen. The method of focal isolation is now largely obsolete.

FOCAL LENGTH. The distance from the second **principal plane** of an optical system to the point at which rays initially parallel to the axis of the system intersect that axis.

FOCAL LENGTH, FRONT. See **front local length.**

FOCAL LENGTH, REDUCED. See **reduced focal length.**

FOCAL LINE. One of the two very short lines in the **principal sections** of a narrow **astigmatic** bundle of light rays, characterized by the fact that all of the rays intersect these two lines.

FOCAL PLANE OF A LENS. A plane normal to the **optical axis** of a lens and passing through a focus of that lens.

FOCAL POWER. A somewhat objectionable name for the reciprocal of the **focal length** of a lens, mirror or optical system.

FOCOMETER. An instrument for measuring the **focal length** of an optical system.

FOCUS. See **conic section.**

FOCUS, PRINCIPAL OR FOCUS POINT. All rays which are emitted from the principal focus in the **object space** will be parallel to the **optical axis** after passing through the optical system. All rays which enter the optical system parallel to the optical axis will meet at the principal focus in the **image space** after interception by the optical system.

FOCUSING. The process of controlling the convergence and divergence of an electron beam, or of a beam of radiation.

FOCUSING COIL OR FOCUSING MAGNET. An assembly producing a magnetic field for focusing an electron beam.

FOCUSING CONTROL. In cathode-ray equipment, the control whereby the electron beam is made to meet the fluorescent screen in a small, well-defined spot.

FOCUSING DUE TO ELECTRON DEFLECTION. Any electrostatic deflection system is also a converging cylindrical lens. Thus, it will cause a beam of electrons traveling in a parallel path to focus at some point after passing through the deflection system.

FOCUSING ELECTRODE. An electrode to which a potential is applied to control the cross-sectional area of the el ctron beam.

FOCUSING, ELECTROSTATIC. A method of focusing an electron beam by the action of an electric field.

FOCUSING, MAGNETIC. A method of focusing an electron beam by the action of a magnetic field. (See **electron lens.**)

FOEHN WIND. On the lee side of mountains, air flowing downhill dry-adiabatically with attendant heating.

FOG. (1) Extra-spectral blackening of a photographic emulsion. (2) A two-phase system consisting of liquid or solid particles or droplets dispersed in a continuous gaseous phase. Condensation and consequent formation of water droplets (or ice crystals) in the air at the earth's surface will produce a fog. Fogs are classified in many ways. One of the simplest is the use of formation cause or process as a basis for differentiation among the various types, which has been followed in the following definitions.

FOG, ADVECTION. **Fog** that owes its existence to the flow of air from one type of surface to another. Surface temperature contrast between two adjacent regions is necessary in causing the formation of advection fogs (1) The usual type of advection fog is formed when relatively warm and moist air drifts over much colder land or water surfaces Examples of this type are found over land when moist air drifts over snow-covered areas, or over water when moist warm air drifts over currents of very cold water The latter happens with southerly or easterly winds blowing from the Gulf Stream over the Labrador current. (2) Coastal and lake advection fog forms when warm and moist air flows offshore onto cold water (summer), or when warm moist air flows onshore over cold or snow-covered land (winter). (3) Sea smoke, arctic fog, or steam fog forms in very cold air when it flows over warm water.

FOG CHAMBER. A confined space in which **supersaturation** of air or other gas is produced by reduction of pressure, cooling, or other means, in order to study the movement and interaction of electrified particles by the condensation (fog tracks) they produce. (See **cloud chamber.**)

FOG DENSITY. The density of an unexposed portion of a sensitometric strip. The density due to fog is not the same in the exposed steps as in the unexposed portion of the sensitometric strip. The relation between the fog density and the total density is compli-

cated, but in general it may be said that, as the total density increases, the fog density becomes less and less. This is due to the fact that the by-products released in the development of the exposed silver halide restrain the development of fog. Hence, in the higher densities, the development of fog is restrained to a greater degree than in the lower densities.

FOG, PRECIPITATION. A **fog** formed in layers of air which are cooler than the precipitation which is falling through them. The greater the temperature difference between relatively warm rain (or snow) and the colder air layer, the more rapidly will the fog develop. Fogs associated with **fronts** are largely precipitation fogs.

FOG, RADIATION. A **fog** that develops in nocturnally-cooled air in contact with a cool surface. Radiation fog forms over land and not over water because water surfaces do not appreciably change their temperature during hours of darkness.

FOG TRACKS. Linear regions of **condensation,** produced in air or other gases that are supersaturated with water vapor, by the passage of electrified particles Fog tracks are useful in following the courses and collisions of such particles. (See **cloud chamber.**)

FOG, UPSLOPE. A **fog** caused by dynamic cooling in air flowing uphill Upslope fog will form only in air that is convectively stable (see **atmospheric stability**) never in air that is unstable, because instability permits the formation of cumulus clouds and vertical currents.

FOLDED DIPOLE ANTENNA. See **antenna, folded dipole.**

FOLLOW-UP SYSTEM. Colloquialism for **servomechanism.**

FOOT. Unit of length, abbreviation ft or f. (1) British: One-third of an imperial yard (2) U.S.: one-third yard or 1200/3937 meter.

FOOT-CANDLE. A unit of **illuminance** or **luminous flux density** when the foot is taken as the unit length. It is the illuminance on a surface one square foot in area on which there is a uniformly-distributed flux of one **lumen,** or the illuminance at a surface all points of which are at a distance of one foot from a uniform source of one candle. The term is synonymous with lumen per square foot.

FOOT-LAMBERT. A unit of **luminance** equal to $1/\pi$ **candle** per square foot, or to the uniform luminance of a perfectly diffusing surface emitting or reflecting light at the rate of one **lumen** per square foot. A foot-candle is a unit of incident light and a foot-lambert is a unit of emitted or reflected light. For a perfectly reflecting and perfectly diffusing surface, the number of foot-candles is equal to the number of foot-lamberts.

FOOT POUND. (1) A unit of work or energy in the f lbf s system of units, being the work done when an average force of one pound (force) produces a displacement of one foot in the direction of the force.

(2) A unit of moment or torque f lbf s system of units, being the time rate of change of angular momentum produced by a force of one pound acting at the end of, and perpendicular to, a radius of one foot from the axis of rotation. More commonly referred to as a pound foot (to distinguish from the unit of work).

FORBIDDEN BAND. In the **band theory of solids,** a range of energies in which there are no electronic levels

FORBIDDEN TRANSITION. In quantum mechanical terms, a transition between two states of a system for which the change in quantum numbers is one that, under the appropriate Pauli **selection rules,** makes the transition less probable than competing allowed transition (see **transition, allowed**)—other things, such as the energy change, being equal As a case in point, transitions involving changes of 2 or more in angular momentum, in units of $h/2\pi$, have often a smaller probability of occurrence than a possible competing "allowed" transition involving a change of only 1. Cases in which "forbidden" transitions occur are:

(1) Intercombination lines such as the 2537 A line ($2^3P_1 - 1^1S_0$) in the spectrum of mercury violate the selection rule of $\Delta S = 0$. However, this rule is true only for pure Russell-Saunders coupling (see **coupling, Russell-Saunders**), and with increase in atomic number, spin-orbit interaction becomes more effective.

(2) The selection principles are deduced by analogy of the behavior of an electrical dipole, and therefore systems having a **quadrupole** moment exhibit the effects of **transi-**

tions forbidden for dipoles, but not for **quadrupole radiation.**

(3) Forbidden transitions may occur as the result of variable magnetic dipole moment.

(4) Forbidden transitions may occur by the action of strong electric fields, either applied externally or produced by neighboring atoms or ions (enforced dipole moment).

FORBIDDEN TRANSITION, NUCLEAR. The term forbidden transition has been taken over from optical spectra and applied to β-ray spectra. Those transformations of a nucleus which result in a change of more than one unit of angular momentum are characterized by this term even when they are highly probable as a result of the orbital angular momentum of the electron and the **neutrino.**

FORCE. (1) In dynamics, the physical agent which causes a change of momentum, measured by the time rate of change of momentum. If the speeds involved are low compared with that of light, a force may be defined as proportional to the **mass** m of a body and to the **acceleration a** of the body which is produced by the force. Thus $\mathbf{f} = km\mathbf{a}$, where k is a constant for a given system of units, and has the dimensionless value unity in length-mass-time systems or $1/g$ in length-force-time systems, g being the acceleration due to gravity. Force is a vector quantity, requiring both a magnitude and a direction for its complete specification.

(2) In statics, the physical agent which produces an elastic strain in a body. Static forces are equated to dynamic forces by the method of allowing a weight to produce a strain and then by allowing the same weight to fall under the action of gravity.

(3) From its initial conception, which was purely mechanical as expressed in (1) and (2), above, the term force extends to denote loosely any operating agency. (See **electromotive force; magnetomotive force; coercive force;** and other special entries under this term which follow.)

FORCE, ATTRACTIVE. A force acting on a particle such that the acceleration of the particle is in the direction of the agency responsible for the force. This agency can be another single particle, a collection of particles or a region acting as the source of a field.

FORCE, CENTRIFUGAL. See **centrifugal force.**

FORCE CONSTANTS OF LINKAGES. Expressions of the forces acting between **nuclei** to restrain relative displacement. They provide the means of measurement of the resistance to stretching of the **valence bond** and the resistance to deformation of the **valence angle,** and they express these factors mathematically.

FORCE, EFFECTIVE. See **effective force.**

FORCE, EXCHANGE. See **exchange force.**

FORCE FACTOR. (a) The force factor of an electromechanical transducer (see **transducer, electromechanical**) is: (1) the complex quotient of the force required to block the mechanical system divided by the corresponding current in the electric system; (2) the complex quotient of the resulting open-circuit voltage in the electric system divided by the velocity in the mechanical system. Force factors (a1) and (a2) have the same magnitude when consistent units are used and the transducer satisfies the principle of reciprocity. (See **reciprocity theorem, acoustical.**) It is sometimes convenient in an electrostatic or piezoelectric transducer to use the ratios between force and charge or electric displacement, or between voltage and mechanical displacement.

(b) The force factor of an electroacoustic transducer (see **transducer, electroacoustic**) is: (1) the complex quotient of the pressure required to block the acoustic system divided by the corresponding current in the electric system; (2) the complex quotient of the resulting open-circuit voltage in the electric system divided by the volume velocity in the acoustic system. Force factors (b1) and (b2) have the same magnitude when consistent units are used and the transducer satisfies the principle of reciprocity.

FORCE FIELD, CONSERVATIVE. A field whose force components satisfy the condition

$$\mathbf{F} = -\nabla V$$

where V is a scalar function of position only. This demands that $\nabla \times \mathbf{F} = 0$. The work done by a conservative force on a particle in its motion between two given points is independent of the path. (See **energy, potential.**)

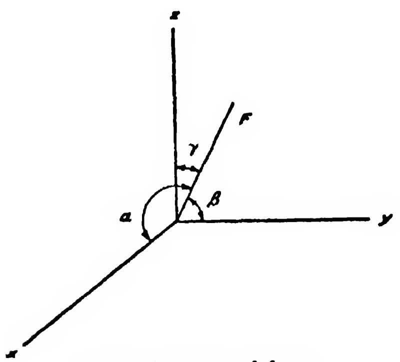
FORCE FUNCTION. The negative of the potential energy of a mechanical system.

FORCE, HEISENBERG. See **Heisenberg force.**

FORCE, IMPRESSED. Any external force acting on a particle in a dynamical system. The resultant force on each such particle can always be resolved into a resultant external impressed force and a resultant internal constraint force. Thus in the case of a particle suspended by a string, the weight is the impressed force and the tension in the string is the constraint force. (See **constraint.**)

FORCE, INSTANTANEOUS (INSTANTANEOUS MECHANOMOTIVE FORCE). The instantaneous force at a point is the total instantaneous force.

FORCE, LINE OF ACTION OF. The direction along which a force acts. This direction can be specified in terms of the direction cosines of the force vector with respect to the coordinate system used.



Line of action of force

If $F_x = F \cos \alpha$, $F_y = F \cos \beta$ and $F_z = F \cos \gamma$ then α, β and γ specify the direction of the line of action of the force.

FORCE, "LOST." In the application of the **d'Alembert principle** by the method of Mach, the "lost" force on the jth particle of a dynamical system is equal to the difference between the external impressed force and the effective force, the latter being equal to the acceleration of the jth particle.

FORCE, MAJORANA. See **majorana force.**

FORCE, MAXIMUM (MAXIMUM MECHANOMOTIVE FORCE). The maximum force for any given cycle is the maximum absolute value of the instantaneous force during that cycle. The unit is the dyne.

FORCE OF CHARGED SYSTEM. If the conductors of a charged set are allowed to move, hence to let the system do work, the energy change of the system is given by:

$$dU = \Sigma V_i dq_i - \Sigma F_i d\xi_i$$

where F_i is the force, in the direction of the displacement $d\xi_i$, on the ith conductor. If the charges are held constant, $dq_i = 0$, and we have

$$\left(\frac{\partial U}{\partial \xi_i}\right)_q = -F_i.$$

If the potentials are held constant, write

$$d(U - \Sigma V_i q_i) = -\Sigma q_i dV_i - \Sigma F_i d\xi_i$$

but

$$U - \Sigma V_i q_i = \tfrac{1}{2}\Sigma V_i q_i - \Sigma V_i q_i = -U$$

(see **energy of a charged system**) so that

$$dU = \Sigma q_i dV_i + \Sigma F_i d\xi_i$$

and

$$\left(\frac{\partial U}{\partial \xi_i}\right)_V = F_i.$$

Note that for constant potential, the energy of the system increases at the same rate mechanical work is done; the sources of potential supply twice as much energy as needed for the mechanical work. The derivatives

$$\left(\frac{\partial U}{\partial \xi_i}\right)_q \quad \text{and} \quad \left(\frac{\partial U}{\partial \xi_i}\right)_V$$

can readily be expressed in terms of

$$\frac{\partial p_{ij}}{\partial \xi_i} \quad \text{and} \quad \frac{\partial c_{ij}}{\partial \xi_i},$$

using the expressions for the energy of a charged system in terms of **coefficients of potential and induction.** Replacing force (F_i) by torque (T_i), and linear displacement ($d\xi_i$) by rotation ($d\theta_i$), the foregoing relations yield the torques of the charged system.

FORCE ON A RIGID CIRCUIT. (See **energy of a system of current circuits.**) If the circuits are rigid, motion will change the **mutual inductances,** M_{ij}, but not the **self-inductances,** $L_i \equiv M_{ii}$. The change of energy of the current system, with motion of the circuits, is:

$$dU = \Sigma\Sigma M_{ij}I_i dI_j + \Sigma\Sigma I_i I_j dM_{ij} - \Sigma F_l d\xi_l$$

$$= \Sigma\Sigma M_{ij}I_i dI_j + \Sigma\Sigma\Sigma I_i I_j \frac{dM_{ij}}{d\xi_l} d\xi_l - \Sigma F_l d\xi_l$$

so for constant currents:

$$\left(\frac{\partial U}{\partial \xi_l}\right)_I = \Sigma\Sigma I_{ij} \frac{dM_{ij}}{d\xi_l} - F_l$$

and

$$\left(\frac{\partial U}{\partial \xi_l}\right)_I = \frac{1}{2} \Sigma\Sigma I_i I_j dM_{ij}/d\xi_l$$

from the expression for the energy of a system of circuits. Therefore

$$F_l = \tfrac{1}{2}\Sigma\Sigma I_i I_j dM_{ij}/d\xi_l$$

and the forces are such as to increase the mutual inductances. As in the case of a charged system, the energy of the system increases as it does work; the set of electromotive forces maintaining the currents does work at twice the rate that mechanical work is done. Substitution of torque for force, and rotation for displacement, in the foregoing yield the torques on the rigid elements of a system of circuits.

FORCE ON CONDUCTOR. A charge dq moving with velocity $\mathbf{v}$ through a steady magnetic field of flux density $\mathbf{B}$ experiences a force

$$\mathbf{F} = dq(\mathbf{v} \times \mathbf{B}).$$

If the charge is moving along a conductor, $dq\mathbf{v} = Id\mathbf{l}$, so the force on an element $d\mathbf{l}$ of a conductor is

$$\mathbf{F} = Id\mathbf{l} \times \mathbf{B}.$$

FORCE PEAK (PEAK MECHANOMOTIVE FORCE). The peak force for any specified interval is the maximum absolute value of the instantaneous force during that interval.

FORCE, RESTORING. The elastic force which acts on a particle or portion of a mechanical system when displaced from equilibrium and whose direction is such as to return the system to equilibrium. In simple cases, the restoring force is linear, i.e., proportional to the first power of the distance. For some physical systems, however, the restoring force may be proportional to the second or higher power of the distance.

FORCE, SHORT-RANGE. See **short-range force.**

FORCE, SPIN-DEPENDENT. See **spin-dependent force.**

FORCE, TANGENTIAL. A force associated with a wheel or disk always acting perpendicular to the radius, e.g., frictional force between rolling wheel and a surface, or frictional force between a belt and a pulley wheel.

FORCE, TENSOR. See **tensor force.**

FORCE, TWO-BODY. See **two-body force.**

FORCE, UNITS OF. A proper force unit must have the following dimensional form in mass, length and time:

$$MLT^{-2}.$$

There are two basic systems of force units, absolute and gravitational. The absolute system defines the force in terms of the effect which gives a unit mass a particular acceleration.

The gravitational system defines the force in terms of the acceleration of gravity on a unit mass at a particular point in the earth's gravitational field. In the absolute system, there are three types of units:

(1) Metric c g sec. A force of one dyne gives a mass of one gram an acceleration of one cm/sec^2.

(2) English lbm ft sec. A force of one poundal gives a mass of one pound an acceleration of one ft/sec^2.

(3) Metric m kg sec. A force of one newton gives a mass of one kilogram an acceleration of one meter/sec^2.

In the gravitational system there are two types of units:

(1) English lbf ft sec. A force of one pound is the force with which earth accelerates a mass of one pound at a point where g = 32.174 ft/sec^2. 1 pound = 32.174 poundals.

(2) Metric c gf sec. A force of one gram is the force with which earth accelerates a mass of one gram at a point where g = 980.665 cm/sec^2. 1 gram = 980.665 dynes.

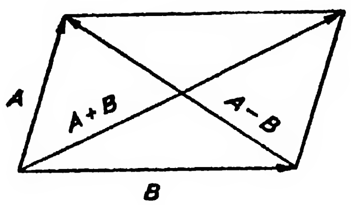
FORCE, WIGNER. See **Wigner force.**

FORCES, CONCURRENT. A system of forces such that there exists a single point common to all the lines of action of the forces.

FORCES, COPLANAR. A system of forces such that the lines of action of all the forces lie in a single plane.

FORCES, PARALLEL. A system of forces such that the lines of action of all the forces are parallel to each other

FORCES, PARALLELOGRAM OF. A geometrical representation by which the sum or difference of two concurrent forces **A** and **B** can be considered as the diagonals of a parallelogram. The two adjacent sides are proportional in length to the magnitude of the forces and their directions coincide with the lines of action of the forces. The diagonal represent-



Parallelogram of forces

ing the sum passes through the origin of the two vectors. The diagonal representing the difference passes through the extremities of the two vectors.

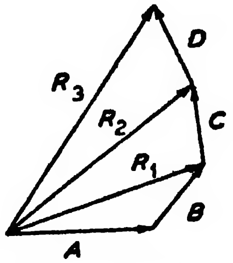
FORCES, POLYGON OF. A geometrical representation by which the sum of two or more concurrent forces can be determined by the successive vector addition of the forces involved

$$\mathbf{R}_1 = \mathbf{A} + \mathbf{B}$$

$$\mathbf{R}_2 = \mathbf{A} + \mathbf{B} + \mathbf{C} = \mathbf{R}_1 + \mathbf{C}$$

$$\mathbf{R}_3 = \mathbf{A} + \mathbf{B} + \mathbf{C} + \mathbf{D} = \mathbf{R}_2 + \mathbf{D}.$$

Each force is represented by a vector proportional in length to the force magnitude and coincident in direction with the line of action of the force.



Polygon of forces

FORCES, TRIANGLE OF. Three concurrent forces which act such that the common point is in translational equilibrium, can be represented by a triangle. The sides of the triangle are proportional in length to the magnitude of the forces and the directions of the sides coincide with the lines of action of the forces. (See **equilibrium of a point; statics.**)

FORCED DOUBLE REFRACTION. **Double refraction** produced in an otherwise isotropic medium as a result of strain.

FORCED OSCILLATION. See **oscillation, forced.**

FORCED VIBRATION. See **oscillation, forced.**

FORCING RESISTANCE. See **resistance, forcing.**

FORENSIC SPECTROSCOPY. The use of **spectroscopy** as an aid in criminal investigations.

FORK RECTIFIER. See **rectifier, fork.**

FORM, BILINEAR. A homogeneous **polynomial** in $2n$ variables $x_1, x_2, \cdots, x_n$; $y_1, y_2, \cdots, y_n$. If **A** is a symmetric **matrix; x, a row vector; y** a **column vector,** then the polynomial may be written in matrix form

$$A(\mathbf{x}, \mathbf{y}) = \tilde{\mathbf{x}}\mathbf{A}\mathbf{y} = \sum_{ij}^{n} A_{ij}x_iy_j$$

The **quadratic form** results when $x_i = y_i$. If the variables are complex and the matrix is **Hermitian,** the form is also called Hermitian

$$H(\mathbf{x}, \mathbf{x}) = \Sigma H_{ij}x_i{}^*x_j = \mathbf{x}^\dagger\mathbf{H}\mathbf{x}; \quad H_{ij} = H_{ji}{}^*$$

where the asterisk denotes the **complex conjugate** and the dagger the **associate matrix.**

FORM FACTOR. (1) Factor introduced into a theory, usually by physical and non-rigorous arguments, to allow consequences of the theory to be computed without contributions from values of a parameter for which the theory is not applicable (see **cut-off**). (2) A means for describing one attribute of the shape of an **alternating-current** wave. The strength of a-c constantly varies in magnitude and direction. The effective value of a-c is equal to the d-c which will produce the same heating effect as the a-c wave, i.e., the root-

mean-square (rms) value. The form factor is the ratio of the rms value of the wave to its average absolute value; the factor is unity for a square wave, and 1.11 for a pure sine wave. It is of importance in the measurement of waves containing harmonics, for it is the ratio of the reading on an rms meter to that on an ideal rectifier-type meter.

FORMANT. A group of **resonances** near a maximum in the transmission of a vowel in the vocal tract.

FORMING, ELECTRICAL (APPLIED TO SEMICONDUCTOR DEVICES). Process of applying electrical energy to a **semiconductor device** in order to modify permanently the electrical characteristics.

FORMULA, ELECTRONIC. A formula that shows the electronic state of each atom in a compound, i.e., the number of positive or negative elementary charges which the atom has acquired by loss or gain, respectively, of its valency electrons.

FORMULA, IONIC. The formula of an ion. In the case of a mono-atomic ion, this formula would consist only of the symbol of the element and the number of elementary charges, positive or negative, carried by the ion. In the case of an ionized radical, it would consist of the symbols of all elements contained, their atomic proportions (number of gram-atomic weights), and the number of net elementary charges carried by the ionized radical, positive or negative. E.g., Na^+, $SO_4^=$, etc.

FORMULA, LEWIS-LANGMUIR. A formula for a substance which shows each atom and the electrons that participate in the valence bonds uniting it to other atoms. For example, this type of formula for methane,

$$\begin{array}{c}\mathrm{H}\\ \mathrm{H}:\overset{\cdot\cdot}{\underset{\cdot\cdot}{\mathrm{C}}}:\mathrm{H},\\ \mathrm{H}\end{array}$$

shows the central carbon atom joined to four hydrogen atoms, in each case by a valence bond composed of a pair of shared electrons. To consider another type of compound, the formula for sodium chloride,

$$\overset{+}{\mathrm{Na}}:\overset{-}{\underset{\cdot\cdot}{\overset{\cdot\cdot}{\mathrm{Cl}}}}:,$$

shows an ionized sodium atom joined to an ionized chlorine atom by electrostatic forces. (See **atom, Lewis-Langmuir.**)

FORMULA, MOLECULAR. A formula that indicates the composition of a substance which contains two or more molecules. Hydrates, for example, are commonly represented by molecular formulas, as $CuSO_4 \cdot 5H_2O$ or $CaSO_4 \cdot 2H_2O$. In such formulas the period ($\cdot$) indicates the intramolecular valence **bond** or bonds.

FORMULA, POLARITY. A formula which indicates in some manner whether a pair of bonding electrons is located equidistantly between the two atoms bonded, as in the case of methane, illustrated under **formula, Lewis-Langmuir,** or whether it is displaced toward one of the atoms, as in the case of a **dative bond** or the extreme case of sodium chloride, where the bond has become truly electrovalent.

FÖRSTERLING PRISM TRAIN. A prism train so designed that it gives constant **deviation** with dispersion equivalent to that of three 60-degree prisms.

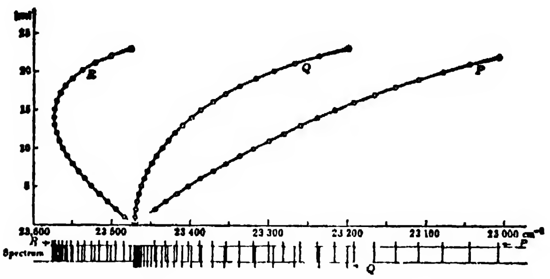
FORTRAT PARABOLA. A graph obtained by plotting an empirical relationship for the wave number of the individual lines (**fine structure** lines) in spectral **bands** (e.g., that of CN). This relationship is of the form:

$$\nu = c + dm + em^2$$

where c, d, and e are constants, and m is a whole number which numbers the successive lines. As is obvious from the equation, the graph is a parabola, and has been called a Fortrat parabola.

Many such spectral bands have one line missing, and the practice is to give the missing line the value $m = 0$ (whence it is called the zero line or null line—and the empty space in the band, the zero gap or null-line gap). Then the values of m to one side of the zero gap become positive and those to the other side negative. The series of lines corresponding to the positive values of m is called the positive branch or R-branch; that corresponding to the negative values is called the negative branch or P-branch. In many band systems, there is a third branch which is called the Q-branch or zero branch. The lines of the Q-branch lie on a parabola whose vertex lies

almost on the abscissa axis. In the formula for the Q-branch, the quadratic term agrees with that for the other two branches.



FORTUITOUS TELEGRAPH DISTORTION. See **distortion, fortuitous telegraph.**

FORWARD DIRECTION. The polarity of the voltage applied to a **rectifier** such that the current flows easily.

FOSTER-SEELEY DISCRIMINATOR. The name given the conventional discriminator used in the detection of FM signals.

FOUCAULT CURRENT. An **eddy current.**

FOUCAULT DIFFRACTION. See **diffraction.**

FOUCAULT GYROSCOPE OR GYROSCOPIC COMPASS. A compass device of practical navigational application which makes use of the tendency of a spinning body to maintain its axis of rotation in a fixed direction against the action of external forces. (See **gyroscope.**)

FOUCAULT KNIFE-EDGE TEST. A concave mirror or a lens may be tested by placing a pinhole-source of light at twice the **focal length** behind the lens or at the **center of curvature** of the mirror (or as near the center as possible). The eye placed at the image of the pinhole should see the entire lens or mirror illuminated. A knife-edge moved across the image immediately in front of the eye will determine where the image is located and will show defects in the lens or mirror by irregular darkening of the image. This is the customary test used by amateur telescope-mirror makers. A diffraction **grating** may be tested in a similar manner using a slit instead of a pinhole.

FOUCAULT PENDULUM. In 1851 Foucault performed his celebrated **pendulum** experiment at Paris, designed to give physical proof that the earth is in rotation about an axis. The pendulum, consisting of a very large iron ball suspended by a steel wire over 200′ long, was suspended from the center of the dome of the Pantheon. Great care was exercised in the support for the wire so that no external forces should be effective at this point other than a vertical force to prevent the system from falling. On the floor, immediately under the pendulum, a layer of fine sand was placed so that the direction of the swing could be observed. The pendulum was started by drawing it to one side with a fine thread and, after the system was at rest, the thread was burned off, thus avoiding any initial lateral motion.

After such a pendulum is started swinging in one plane, it is soon observed that the plane of swing is apparently deviating slowly (in the clockwise direction in the northern hemisphere and the opposite in the southern). The rate at which the plane of swing deviates is equal to 15° per sidereal hour (cf. **time**) multiplied by the sine of the latitude Thus at the pole it would make a complete rotation in one sidereal day, while at the equator it would not rotate at all At Paris (latitude 48° 50′ N.) the rate of deviation is about 11° 18′ per hour.

Foucault reasoned quite correctly that, in accordance with Newton's Laws of Dynamics, the direction in space of the plane of swing should not change unless the pendulum was acted upon by some external force other than that of gravitation and the counteracting force parallel to the direction of gravitation at the support That the direction of the plane does apparently change can be accounted for only on the hypothesis that the earth is in rotation. Foucault's demonstration attracted wide scientific and popular attention and was accepted as a conclusive proof that the earth does rotate upon an axis, a fact which was not universally accepted at that time.

FOUCAULT PRISM. See **prism, Foucault.**

FOUCAULT ROTATING MIRROR. Foucault arranged a light-source, lens, rotating mirror and distant mirror While light was traveling from the rotating mirror to the distant mirror (20 meters) and back, the rotating mirror turned slightly so that after the second reflection from the rotating mirror the reflected beam was slightly displaced (2′ 40″) from its original path. From these data and

the angular speed of the rotating mirror, Foucault computed a velocity of light as 2.98×10^{10} cm/sec. The faintness of the returned beam prohibited use of a greater light-path. (See **Michelson rotating mirror.**)

FOUNTAIN EFFECT. See **helium liquid, properties of.**

FOUR-FACTOR FORMULA.

$$k = [\eta\epsilon pf].$$

This equation gives the multiplication factor in an infinite thermal **reactor,** i.e., one with no leakage. η is the average number of fast fission neutrons emitted as a result of the capture of one thermal neutron in fuel material. ϵ is the fast-fission factor, the ratio of the total number of fast neutrons produced by fissions due to neutrons of all energies, to the number resulting from thermal neutron fissions alone. p is the fraction of the fast (fission) neutrons which escape capture while being slowed down. f is the ratio of the number of thermal neutrons absorbed in fuel to the total number of thermal neutrons absorbed (in fuel plus moderator). k, the infinite multiplication factor, is the ratio of the average number of thermal neutrons produced (and hence absorbed) in one generation to the number in the preceding generation; unless k exceeds unity, a critical system of finite size is impossible.

FOUR-FORCE. The **four-vector** describing the rate of change of **four-momentum** along the **space-time path** of a particle:

$$m_0 \frac{dv_\mu}{ds}.$$

(m_0 is the rest mass.)

FOUR-MOMENTUM OF A CLASSICAL PARTICLE. The **four-velocity** times the **rest-mass** of the particle.

FOUR-VECTOR. A set of four quantities which transform under a **Lorentz transformation** as a vector in **Minkowski space.**

FOUR-VELOCITY. The four quantities

$$v_\mu = \frac{dx_\mu}{ds}$$

describing the velocity of a classical particle in relativity theory, where d/ds denotes differentiation with respect to the **proper time** of the particle. The four-velocity is a four-vector of length i, and thus depends on only three independent variables, the ordinary velocity components.

FOURIER ANALYSIS. The process of finding the representation of a function in a **Fourier series.**

FOURIER-BESSEL TRANSFORM. The functions defined by

$$f(y) = \int_0^\infty F(x)J_m(xy)xdx;$$

$$F(x) = \int_0^\infty f(y)J_m(xy)ydy$$

are a pair of **Fourier-Bessel transforms.** The quantity J_m is a **Bessel function** of order m.

FOURIER INTEGRAL. A relation obtainable from the **Fourier transform,** which is a generalization of the **Fourier series** for the range $-\infty < x < \infty$. It can be written as

$$f(x) = \frac{1}{2\pi}\iint_{-\infty}^{\infty} f(\xi)e^{iy(x-\xi)}dyd\xi$$

or, if $f(x)$ is real, in a more common form

$$f(x) = \frac{1}{2\pi}\iint_{-\infty}^{\infty} f(\xi)\cos y(x-\xi)dyd\xi.$$

FOURIER, LAW OF. The rate of heat flow at a given point in a body is proportional to the area of the cross-section and the temperature gradient, both at the given point. The form of this relationship is:

$$\frac{dQ}{dt} = -kA\frac{dT}{dl}$$

where Q is quantity of heat, t is time, k is the proportionality constant (**thermal conductivity**), A is the cross-sectional area, T is temperature, and l is distance in the direction of heat flow, here taken normal to A.

FOURIER SERIES. A single-valued function, continuous except possibly for a finite number of finite discontinuities in the interval $-\pi$ to π, and with only a finite number of maxima and minima in that interval, may be represented within the interval by a Fourier series

$$f(x) = \sum_{n=1}^{\infty} a_n \sin nx + \tfrac{1}{2}b_0 + \sum_{n=1}^{\infty} b_n \cos nx,$$

where the coefficients are given by

$$a_n = \frac{1}{\pi}\int_{-\pi}^{\pi} f(\xi) \sin n\xi d\xi;$$

$$b_n = \frac{1}{\pi}\int_{-\pi}^{\pi} f(\xi) \cos n\xi d\xi.$$

A change of variable may be made so that the interval extends from 0 to π, 0 to 2π, l to $-l$, etc. The series may be generalized to permit the expansion of a function of several variables. If the function is periodic, with period 2π, the Fourier series represents it for all values of x.

FOURIER TRANSFORM. Subject to certain restrictions, $f(y)$ is the **Fourier transform** of $F(x)$, where

$$f(y) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} e^{ixy}F(x)dx;$$

$$F(x) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} e^{-ixy}f(y)dy.$$

In some applications, the factors $1/\sqrt{2\pi}$ are modified.

FOURTH DIMENSION. The time at which an event occurs, represented as the fourth coordinate of **Minkowski space.**

FOVEA. The central portion of the **retina** of the eye where vision is most distinct. The fovea of a normal eye subtends an angle of about 2°.

FRACTION. An indicated quotient of two quantities.

FRACTION, COMMON. The indicated **quotient** of two integers. If the quotient is less than one, the fraction is **proper**; otherwise, **improper.**

FRACTION, CONTINUED. An infinite sequence $\{s_n\}$ with members

$$s_0 = b_0; \quad s_1 = b_0 + a_1/b_1;$$

$$s_2 = b_0 + \cfrac{a_1}{b_1 + \cfrac{a_2}{b_2}};$$

$$s_3 = b_0 + \cfrac{a_1}{b_1 + \cfrac{a_2}{b_2 + a_3/b_3}}; \quad \cdots,$$

formed from the sequences $a_1, a_2, a_3, \cdots$ and $b_0, b_1, b_2, \cdots$. The term s_n is found by replacing the denominator of s_{n-1} by $(b_{n-1} + a_n/b_n)$. When there are a finite number of terms, the fraction is called terminating; if there are an infinite number of terms, nonterminating.

FRACTION EXCHANGE. A number, varying from 0 to 1.0, denoting the progress of an **isotopic exchange reaction,** which is defined by the expression

$$f = \frac{s - s_0}{s_\infty - s_0}$$

where f is the exchange fraction and s, s_0 and s_∞ are the specific activities of one of the reactants at time t, zero-time and infinite time (i.e., at equilibrium), respectively.

FRACTION, PARTIAL. When a given **rational fraction** is resolved into a sum of simpler fractions the individual terms in the sum are called **partial fractions.** The process of resolving a fraction in this way is the inverse process to that of reducing to a common denominator. If the fraction is of the form $f(x)/g(x)$, where the degree of the numerator is less than that of the denominator, $g(x)$ may be written as

$$g(x) = a_0(x - x_1)^{r_1}(x - x_2)^{r_2} \cdots$$
$$(x^2 + 2b_1x + c_1)^{s_1}(x^2 + 2b_2x + c_2)^{s_2} + \cdots.$$

Here a_i is one of the real roots of $g(x) = 0$, it being repeated r_i times. The quadratic expressions arise from conjugate complex roots of the polynomial, each occurring s_i times. Each linear factor in $g(x)$ gives rise to terms of the form

$$\frac{A_1}{x - a} + \frac{A_2}{(x - a)^2} + \cdots + \frac{A_r}{(x - a)^r}$$

where the A_i are constant factors, a is any one of the a_i roots and r corresponds to r_i. Similarly, if $Q(x) = (x^2 + 2bx + c)$, the quadratic factors give terms of the form

$$\frac{B_1 + C_1x}{Q} + \frac{B_2 + C_2x}{Q^2} + \cdots + \frac{B_s + C_sx}{Q^s}.$$

The undetermined coefficients A_i, B_i, C_i in these fractions may be obtained by clearing of fractions and equating coefficients of like powers of x on both sides of the equality, which is an identity in x; or by other special

devices, such as substituting special values of x. An **integral** may often be evaluated by converting the integrand into a sum of partial fractions.

FRAME. In television and facsimile, the total area, occupied by the picture, which is scanned by the **picture signal.**

FRAME FREQUENCY. In television, the number of times per second that the **frame** is scanned.

FRAME OF REFERENCE. A set of lines or surfaces used for defining coordinates that define positions, directions, velocities, etc.

FRAMER. In **facsimile,** the control which positions the reproduced image correctly with regard to the original.

FRAMEWORK. A system of rigid or deformable bodies of arbitrary sizes and shapes fastened together to form a whole, which can be in equilibrium under the action of suitable forces. For example, a bridge truss.

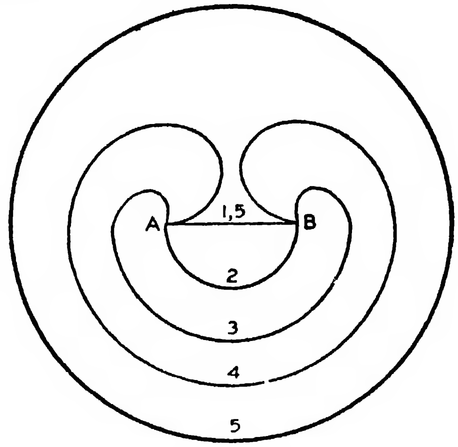
FRAMEWORK, EQUILIBRIUM OF. See **framework.**

FRAMING CONTROL. (1) In television, a centering or width control. (2) In facsimile, the control which adjusts the horizontal position of the picture.

FRANCIUM. Radioactive element. Symbol Fr. Atomic number 87.

FRANCK-CONDON PRINCIPLE. An electronic transition in a molecule or crystal takes place so rapidly that the positions and velocities of the nuclei are virtually unchanged in the process. Therefore, the positions and velocities of the nuclei are practically unchanged during electronic transitions, which can therefore be represented by vertical lines on the potential energy curves. Only transitions satisfying these conditions occur with reasonable probability.

FRANK-READ SOURCE. A mechanism for the continuous generation of **dislocations,** and hence allowing for **plastic deformation** of crystals. A segment of **dislocation line** (1) anchored at its ends, A, B, can be pulled out into an arc (2), which may then fold back round the anchored ends (3) until it meets itself (4), whereupon a closed dislocation loop is detached, whilst the original line is reformed (5). This process may evidently be repeated indefinitely, the successive **dislocation loops** moving out to the surface of the crystal.



Frank-Read mechanism for multiplication of dislocations, showing successive stages in the generation of a dislocation loop by the segment BC of a dislocation line. The process can be repeated indefinitely. (By permission from "Introduction to Solid State Physics" by Kittel, Copyright 1953, John Wiley & Sons)

FRANKLIN EQUATION. The energy level E of sound in a room as a function of time after cutting off the source:

$$E = E_0 e^{-\frac{c\bar{a}S}{4V}t},$$

where E_0 is the initial sound level, c is the velocity of sound, S is the exposed surface area, V is the volume of room, t is the time, $\bar{a}$ is the mean sound absorption coefficient.

For **dead rooms,** this equation must be replaced by **Eyring's equation.**

FRASER METHOD FOR OSMOTIC PRESSURE. The apparatus consists of a clay cell with a membrane, usually copper ferrocyanide, deposited on its exterior. The cell is filled with solvent and is connected to a glass U-tube open to the atmosphere. A bronze cylinder surrounds the cell and contains the solution. Attached to the cylinder is a pressure-measuring device to record the excess pressure as the solvent passes through the membrane into the solution.

FRAUNHOFER DIFFRACTION. Discussed under **diffraction.**

FRAUNHOFER LINES. The dark lines constituting the **absorption spectrum** exhib-

ited by sunlight are frequently called the Fraunhofer lines. There are thousands of these lines, of which Fraunhofer, early in the 19th century, first observed the most prominent. To these particular lines he assigned letters for reference purposes. These lines, together with their origin and approximate wavelengths, are listed as follows:

A	Terrestrial oxygen	7594 A	(extreme red)
B	Terrestrial oxygen	6867 A	(red)
C	Hydrogen	6563 A	(red)
D_1	Sodium } doublet	5896 A	(yellow)
D_2	Sodium } doublet	5890 A	(yellow)
E	Iron	5270 A	(green)
F	Hydrogen	4861 A	(blue)
G	Iron and Calcium (group)	4308 A	(violet)
H	Calcium	3968 A	(extreme violet)

The lines of solar origin are due to absorption by gases and vapors in solar **atmosphere.**

FRAUNHOFER REGION. In antenna terminology, that region of the field in which the energy flow from an **antenna** proceeds essentially as though coming from a point source located in the vicinity of the antenna. If the antenna has a well-defined **aperture** D in a given **aspect,** the Fresnel region in that aspect is commonly taken to exist at distances greater than $2D^2/\lambda$ from the aperture, λ being the wavelength

FREDHOLM EQUATION. A special type of **integral equation,** the one of **second kind** being

$$\phi(x) = f(x) + \lambda \int_a^b K(x,z)\phi(z)dz$$

where a, b, λ are constants, the **kernel,** $K(x,z)$ and $f(x)$ are given; ϕ is sought as a function of x, the independent variable. If the left-hand side of the equation equals zero, it becomes of the **first kind.** Either could also be **homogeneous,** i e , $f(x) = 0$.

FREDHOLM METHOD. A method of solving **integral equations** when the resolvent (see **Liouville-Neumann series**) is the ratio of two infinite series.

FREE-BODY DIAGRAM. A diagram of a body, or part of a body, with the forces acting upon it indicated.

FREE DISCHARGE. See under **discharge, free.**

FREE ELECTRON THEORY OF METALS. The most characteristic property of a **metal** is its **electrical conductivity.** It was early recognized (by Drude) that this could be explained if the electrons in the metal were relatively free to move. A model of a metal as a gas of free electrons, moving in the region of nearly uniform positive potential created by the **ions** of the **crystal lattice,** although satisfactory in some respects, led to serious difficulties, until it was pointed out by Sommerfeld that the electrons must obey the **Pauli exclusion principle** and hence constitute a highly degenerate **Fermi-Dirac gas.** On this basis, one can calculate the **electronic specific heat, magnetic susceptibility, Hall coefficient, Wiedemann-Franz ratio, thermionic emission,** and other physical properties

The reason for the success of this simple theory is that in certain elements, notably the alkali metals, the outer electrons are only very loosely bound to the remainder of the atom, and when the atoms are brought together to make up the crystal lattice these electrons can jump from ion to ion as if they were free To understand the behavior of the more complex metals, and of **semiconductors,** it was necessary to introduce the further complications of the **band theory of solids.**

FREE ENERGY. There are two quantities to which this term has been applied (1) The Gibbs free energy, which is also called the Gibbs function and the thermodynamic potential, is most generally understood when the term free energy is used without qualification It is defined by the equation

$$G = U - TS + pV$$

where U is the internal energy (see **energy, internal**), T, the absolute temperature, S, the **entropy,** p, the pressure, V, the volume and G, the Gibbs free energy (the letter F is also widely used to denote this quantity). (See also **free energy change.**) (2) The Helmholtz free energy, which was called the psi function, and which is perhaps most commonly known as the work function. It is defined by the equation

$$A = U - TS$$

where U is the internal energy, T, the absolute temperature, S, the entropy and A, the Helmholtz free energy. (The letter ψ or the letter F are sometimes used instead of A for this quantity.) The decrease in A is equal to the maximum work done on the system in a constant-temperature, reversible change. In terms of the partition function, $A = -RT \ln Z$. Like the Gibbs free energy, the Helmholtz free energy is a **thermodynamic potential,** although the latter term is commonly used to refer specifically to the Gibbs free energy.

FREE ENERGY CHANGE. The change in the Gibbs free energy (see **free energy (1)**) for a chemical reaction, defined as

$$\Delta G = \sum_{r=1}^{n} \nu_r g_r$$

where g_r is the molar Gibbs free energy of the rth component in the pure state, under the same conditions of temperature and pressure as those in which the reaction takes place. ν_r is the stoichiometric coefficient of the rth component.

This quantity ΔG is equal to the *maximum net* work available (i.e., work, other than work of expansion, in a reversible process) for a given change in state under constant temperature and pressure (See also **standard free energy increase.**)

FREE ENERGY FUNCTION. Used particularly in connection with homogeneous gas reactions. Given by the expressions

$$-\frac{G^0 - U_0{}^0}{T} \quad \text{or} \quad -\frac{G^0 - H_0{}^0}{T}$$

where G^0 is the molar Gibbs free energy (see **free energy (1)**), and $U_0{}^0$ the **internal energy** at the absolute zero, which is equal to the **enthalpy** at the absolute zero, $H_0{}^0$. The superscripts 0 refer to the standard state (for a gas, 1 atmosphere pressure). These expressions are also equal to

$$R \ln \frac{Z^0}{N}$$

where R is the **gas constant**, Z^0 the **partition function** of the ideal gas in the standard state, and N the **Avogadro number.**

FREE ENERGY INCREASE, STANDARD. See **standard free energy increase.**

FREE ENERGY OF IONS, STANDARD. See **ions, standard free energy of.**

FREE ENERGY, STANDARD. See **standard free energy increase.**

FREE FIELD. See **field, free.**

FREE-FIELD CURRENT RESPONSE. See **response, free-field current.**

FREE-FIELD ROOM. See **anechoic room.**

FREE-FIELD VOLTAGE RESPONSE. See **response, free-field voltage.**

FREE GRID. The **grid** of an electron **tube** which has no electrical connection to it. Such a condition is highly undesirable, especially in vacuum tubes, since the grid will accumulate a charge which cannot leak off, and which will alter the operation of the tube. If the charge remained fixed it would not be so serious, but the accumulated charge is very sensitive to external conductors, thus bringing the hand near a tube with a free grid will cause a redistribution of the electrons accumulated on the grid and cause the plate current to vary erratically.

FREE IMPEDANCE. See **impedance, free.**

FREE MOTIONAL IMPEDANCE. See **impedance, free motional.**

FREE OSCILLATION. See **oscillation, free.**

FREE PROGRESSIVE WAVE. See **wave, free progressive.**

FREE RADICAL. An unsaturated molecular fragment in which some of the valence electrons remain free, i.e., do not partake in bonding. Examples are methyl ($CH_3\cdot$) or phenyl ($C_6H_5\cdot$) radicals. Clear experimental evidence is available of their existence in various systems, especially in gaseous ones, although their **half-life period** is of the order of thousandths of a second.

FREE-RUNNING. See **astable.**

FREE-RUNNING FREQUENCY. See **frequency, free-running.**

FREE-SPACE FIELD INTENSITY. See **field intensity, free-space.**

FREE SURFACE. A phase boundary between two fluids. In hydrostatic equilibrium such a surface must coincide with a gravitational equipotential (neglecting the effects of

surface tension), and its movements about the equilibrium position are considered in the theory of **surface waves.**

FREE VIBRATION. See **oscillation, free.**

FREE VOLUME. A liquid differs from a solid having the same type of packing of the molecules in having a certain additional volume, the free volume, which provides the necessary looseness in the structure to permit free movement of the molecules The concept of free volume is used in several theories of the liquid state.

FREE WAVE. See **wave, free progressive.**

FREE-WHEEL RECTIFIER. A rectifier placed across (backwards) a d-c, highly-inductive load which is driven from a control amplifier such as a thyratron or **magnetic amplifier.** This rectifier, by providing a path for the inductive load current during the intervals while the control amplifier is normally "off" or non-conducting, permits continuous control of load current which might otherwise be impossible to attain

FREEDOM, DEGREES OF. (1) The number of independent coordinates necessary for the unique determination of the position of every particle in a dynamical system is the number of degrees of freedom. Each degree of freedom is represented by a coordinate which can vary with time independently of all the rest Thus a single particle which may move anywhere in three-dimensional space has three degrees of freedom. A particle constrained to move on a surface has two degrees of freedom, etc.

(2) In the statement of the **phase rule,** one of that number of variable factors such as pressure, temperature or concentration, which must be fixed to define completely the state of the system.

(3) The number of independent **meshes,** or the number of independent **cut-sets** that may be selected in a **network.**

FREEZE. To solidify from the liquid state.

FREEZING CURVE. A plot of the temperature (or of any quantity which is a function of temperature) against time, obtained as a substance is allowed to cost from above its **freezing point** to below that temperature. Freezing curves are used in the calibration of **thermocouples** and other temperature measuring devices.

FREEZING POINT. The temperature at which a liquid becomes a solid. This is not always identical with the melting point of the solid, for many mixtures, particularly of fats and waxes, do not solidify until they have been cooled several degrees below their melting points. If a liquid be cooled under pressure the freezing point rises if the solid is of higher density than the liquid; if it is of lower density, as in the case of water, the freezing point is lowered. Since the freezing point varies slightly with pressure, the pressure should be stated in reporting a freezing point. However, atmospheric pressure is commonly understood unless otherwise specified.

FREEZING POINT, DEPRESSION OF. The freezing point of a solution is, in general, lower than that of the pure solvent and the depression is proportional to the active mass of the solute. For dilute solutions

$$\Delta T = Km$$

where ΔT is the lowering of the freezing point, K the **cryoscopic constant** for the given solvent, and m the molality of the solution.

FREEZING POINT DEPRESSION, MEASUREMENT OF. In the Beckmann method the freezing point of pure solvent and of solution is measured by a special type thermometer, the "Beckmann thermometer." The solvent or solution is contained in a double-walled glass apparatus and placed in a freezing mixture not more than 5°C below the freezing point of the solvent. By rapid stirring when the liquid has supercooled about ½° crystallization is induced and the temperature rises to the freezing point.

In the equilibrium method a relatively large amount of solvent crystals are allowed to form and the system allowed to come to equilibrium. The temperature is recorded and some of the solution withdrawn and analyzed.

In the Rast method, camphor is used as solvent. This substance has a very high molar depression constant, and Rast devised a micro-method for the determination of molecular weights. Melting points may be measured with an ordinary thermometer.

FRENKEL DEFECT. A lattice **vacancy** created by removing an ion from its site and placing it at an **interstitial position** within the lattice. The equilibrium concentration of Frenkel defects is

$$n = C_F(NN')^{1/2}e^{-W/2kT}$$

where N, N' are the densities of lattice points and interstitional positions, W is the work necessary to make the defect, and C_F is a numerical factor of the order of 100.

FREQUENCY. (1) In general, the number of repetitions of a periodic process per unit time, i.e., the inverse of the periodic time. (2) In electricity, frequency is the number of complete alternations per second of an **alternating current.** Sixty cycles per second is becoming the standard frequency for a-c generation in the United States. Elsewhere 25 and 50 cycles per second have some vogue In an **alternator,** the number of alternations per second of the output is the speed, in revolutions per second, multiplied by half of the number of poles. The number of poles in alternators is usually 2 or 4 for steam turbine-driven alternators, or 24, 26, 28, 30, 36, 48, or 60 in the case of engine-driven alternators. (3) In **acoustics,** the frequency represents the number of sound waves passing any point of the sound field per second. (4) In the case of **light** or other **electromagnetic radiation,** frequency may be expressed in this same way but is usually so enormous (500 million million per second for yellow light) that wavelengths or wave numbers (reciprocal of wavelength measured in cm) are ordinarily used instead. **Radio frequencies** are commonly given in thousands of cycles (kilocycles) or millions of cycles (megacycles) per second.

FREQUENCY ALLOCATION. The assigned carrier-frequency of a radio-transmitting station.

FREQUENCY, ANGULAR OR RADIAN. The frequency expressed in radians per second. It is equal to the frequency in cycles per second multiplied by 2π.

FREQUENCY, AUDIO. Any frequency corresponding to a normally audible sound wave. Audio frequencies range roughly from 15 to 20,000 cycles per second. The word "audio" may be used as a modifier to indicate a device or system intended to operate at audio frequencies.

FREQUENCY BAND. (1) The band or channel of frequencies associated with a **carrier** under **modulation.** (2) A group of different carrier frequencies all designated for the same purpose. In this sense there may be many frequency channels within the given band. Thus the standard broadcast band contains many broadcast channels, each having its carrier spaced 10 kc from the next. In some types of radio service the only restriction on the carrier value is that it be kept within the allocated band.

FREQUENCY, BASIC. Of an oscillatory quantity having sinusoidal components with different frequencies, the frequency of the component considered to be the most important In a driven system, the basic frequency would, in general, be the driving frequency, and in a periodic oscillatory system, it would be the fundamental frequency.

FREQUENCY, BREAK. The frequency at which an abrupt change in slope occurs on log-log, asymptotic, frequency-amplitude characteristic.

FREQUENCY, CENTER. (1) The average frequency of the emitted wave when modulated by a sinusoidal signal. (2) The frequency of the emitted wave without modulation.

FREQUENCY CHANGER. Wherever there is to be an interchange of electrical energy between two systems which operate at different **frequencies,** the tie together must be through the medium of a frequency changer, since it is impossible to have two units, e g., **alternators,** electrically connected to the same line operating at different frequencies. The one operating at higher frequency will tend to motor the other, and take unto itself enough of the load so that through the slowing down of it, and the speeding up of the slower, their frequencies will coincide. The simplest plan for connection of two such systems, and the one usually employed, is to couple, mechanically, two rotating machines of the **synchronous motor** or **generator** type, which have, respectively, the correct number of electrical poles to permit one to operate at the frequency of one system, while the other is at the frequency of the other system, both, of course, having the same rotative speed. This is relatively simple in the case of the drawing of power, say, from a 60-cycle system to supply

energy for 25-cycle use, but has serious disadvantages as a means of interconnecting two power systems of different frequency, each having considerable amount of generating equipment. Any slight alteration in the relative frequencies of these two systems results in heavy fluctuations of the frequency changer load, and necessitates the employment of extremely large and bulky frequency changers. Nevertheless, this is the system usually employed. Fortunately, the necessity for such frequency changing is rare in this country at the present time. (See also **frequency multiplier; frequency divider.**)

FREQUENCY CHANNEL. See **radio communication;** also **carrier frequency.**

FREQUENCY CONVERSION TRANSDUCER. See **transducer, conversion.**

FREQUENCY CONVERTOR (MIXER). See **transducer, conversion.**

FREQUENCY-CONVERTOR TUBE. See **tube, mixer.**

FREQUENCY, CUTOFF. See **cutoff frequency.**

FREQUENCY DEMODULATOR. See **demodulator, frequency.**

FREQUENCY DEPARTURE. The amount of variation of a **carrier frequency** or center frequency from its assigned value. The term "frequency deviation," which has been used for this meaning, is in conflict with this essential term as applied to phase and frequency modulation (see **modulation, phase** and **modulation, frequency**) and is, therefore, to be avoided for use in the above sense.

FREQUENCY DEVIATION. (1) In amplitude-modulated or continuous-wave transmission, the amount by which the **carrier frequency** varies from its assigned value. See **frequency departure** in this connection. (2) In frequency modulation, the peak-difference between the instantaneous frequency of the **modulated wave** and the carrier frequency.

FREQUENCY DISCRIMINATOR. See **discriminator.**

FREQUENCY DISTORTION. See **amplitude-frequency distortion.**

FREQUENCY DIVIDER. A device delivering output voltage at a frequency that is a proper fraction of the input frequency. Usually the output frequency is an integral submultiple or an integral proper fraction of the input frequency. (See also **transducer, harmonic-conversion.**)

FREQUENCY DIVISION. A process of propagating two or more information-bearing signals over a common path by using a different frequency band for the transmission of each signal. (See **frequency-division multiplex.**)

FREQUENCY - DIVISION MULTIPLEX. The process or device in which each modulating wave modulates a separate **subcarrier** and the subcarriers are spaced in frequency. Frequency division permits the transmission of two or more signals over a common path by using different frequency bands for the transmission of the intelligence of each message signal.

FREQUENCY DOUBLER. A device delivering output voltage at a frequency that is twice the input frequency.

FREQUENCY DRIFT. The change in frequency of an **oscillator** as a function of time. The change may be due to changes in temperature, supply voltages, humidity, or physical dimensions caused by wear.

FREQUENCY, FIELD. In television, the product of frame frequency (see **frequency, frame**) multiplied by the number of fields contained in one frame.

FREQUENCY, FRAME. In television, the number of times per second that the **frame** is scanned.

FREQUENCY, FREE-RUNNING. The frequency at which an **oscillator** operates in the absence of a **synchronizing signal.**

FREQUENCY, FUNDAMENTAL. (1) The lowest possible frequency of vibration of a system characterized by normal modes of vibration (for example, a vibrating string or organ pipe). (See **wave, stationary.**) (2) Otherwise stated as the greatest common divisor of the component frequencies of a periodic wave or quantity. (3) Of a periodic quantity, the frequency of a sinusoidal quantity which has the same frequency as the periodic quantity.

FREQUENCY HARMONICS. The permissible characteristic frequencies of a vibrating system subject to boundary restrictions (for example, a stretched string fastened rigidly at both ends, an organ pipe open at both ends, etc.). The lowest permissible frequency is called the fundamental. The higher frequencies are called the 2nd, 3rd, 4th, etc., harmonics. The fundamental is ordinarily referred to as the first harmonic. (See **overtone.**)

FREQUENCY-HYSTERESIS. An effect produced by coupling an **oscillator** to a load through a transmission line very long in comparison to a wavelength. (See **long-line effect.**)

FREQUENCY, INFRASONIC (SUBSONIC FREQUENCY). A frequency lying below the audio-frequency range. (See **frequency, audio.**) The word "infrasonic" may be used as a modifier to indicate a device or system intended to operate at infrasonic frequencies.

FREQUENCY, INSTANTANEOUS. The time rate of change of the angle of a wave which is a function of time If the angle is measured in radians, the frequency in cycles is the time rate of change of the angle divided by 2π.

FREQUENCY, LINE. In television, the number of times per second that a fixed vertical line in the picture is crossed in one direction by the **scanning spot.** Scanning during vertical return intervals is counted.

FREQUENCY, LOWEST-USEFUL HIGH. The lowest high frequency effective at a specified time for **ionospheric** propagation of radio waves between two specified points. This is determined by factors such as absorption, transmitter power, antenna gain, receiver characteristics, type of service, and noise conditions.

FREQUENCY, MAXIMUM USABLE. The upper limit of the frequencies that can be used at a specified time for radio transmission between two points and involving **propagation** by reflection from the regular ionized layers of the **ionosphere.** Higher frequencies may be transmitted by sporadic and scattered reflections.

FREQUENCY MEMORY. A memory which consists of an **oscillator** with a number of possible oscillation frequencies. Normally in the nonoscillating state, it will start and remain oscillating at the frequency of a momentary input voltage if the frequency of this voltage corresponds to one of the possible oscillation frequencies.

FREQUENCY METER. Most modern frequency meters for radio use are not **instruments** in the usual sense but are really several instruments and associated apparatus. The old absorption type wavemeter might be called a single instrument, but it is not used except for rough measurements. It consists of a **coil** and **condenser** in series with some sort of indicator. Modern precision measurement of frequency utilizes a comparison process. The fundamental for this is the rotation of the earth High-grade crystal **oscillators** are used to generate medium values of radio frequency, the output being compared with the rotation of the earth by synchronous clocks or by comparison with another oscillator which is so checked. Associated with this oscillator are various **multi-vibrator** oscillators serving as **frequency dividers** to give an extensive series of accurately known frequencies. The frequency to be measured is compared with the closest of these known frequencies by heterodyning and the resultant difference frequency (an **audio frequency**) determined in one of several ways. (See **heterodyne.**) Very high frequencies are measured by exciting standing waves on an open or shorted transmission **line** and measuring the linear distance between nodes or antinodes of these waves. The frequency is then obtained by dividing the velocity (3×10^{10} cm/sec) by the wavelengths in centimeters. For very accurate measurements several corrections must be applied to this method but it is sufficiently accurate for many purposes without the corrections. (See **Lecher wires.**)

A common frequency-measuring **instrument** used for commercial power circuits is the vibrating reed instrument. This consists of many reeds, each tuned to a different frequency (commonly a half-cycle apart), which are set in vibration by the alternating flux of a **solenoid** connected across the circuit to be measured.

Another and more accurate frequency-measuring instrument for commercial circuits depends for its operation upon the effect on the moving element of the currents in two shunt

circuits. One of these contains inductance and the other capacitance, so the effect of a change in frequency is opposite in the two circuits. Since they are connected across the circuit to be measured their currents change with frequency and hence the moving element is deflected.

FREQUENCY METER, ABSORPTION. A frequency or wavemeter consisting of a calibrated, tuned circuit and some form of indicator to indicate **resonance.** The meter is adjusted until maximum energy is absorbed from the source, at which time the resonance frequency of the tuned circuit will be very nearly that of the unknown frequency. Also known as a wavemeter.

FREQUENCY METER, HETERODYNE. A frequency meter which causes a known, adjustable frequency to be **heterodyned** with the unknown until a zero **beat note** is obtained. The unknown frequency is then exactly that of the known frequency.

FREQUENCY MODULATION (FM). Angle modulation (see **modulation, angle**) of a sine-wave carrier in which the instantaneous frequency of the modulated wave differs from the carrier frequency by an amount proportional to the instantaneous value of the modulating wave. Combinations of phase and frequency modulation are commonly referred to as "frequency modulation."

FREQUENCY - MODULATION BROADCAST BAND. The band of frequencies extending from 88 to 108 megacycles, which includes those assigned to non-commercial educational broadcasting.

FREQUENCY - MODULATION BROADCAST CHANNEL. A band of frequencies 200 kilocycles wide, designated by its center frequency. Channels for FM broadcast stations begin at 88.1 megacycles and continue in successive steps of 200 kilocycles to and including 107.9 megacycles.

FREQUENCY - MODULATION BROADCAST STATION. A station employing frequency modulation (see **modulation, frequency**) in the FM broadcast band and licensed primarily for the transmission of radiotelephone emissions intended to be received by the general public.

FREQUENCY - MODULATION EXCITER UNIT. See **exciter.**

FREQUENCY MODULATION, G.E. SYSTEM. A system which accomplishes frequency modulation with a special tube called a phasitron. (See **tube, phasitron.**)

FREQUENCY-MODULATION MEASUREMENTS BY "BESSEL-ZERO" METHOD. The "Bessel-Zero" method of measurement of the frequency deviation and audio-frequency response of an FM transmission is based on the fact that the amplitude of the center-frequency component of the energy emitted from an FM transmitter varies as the amplitude or frequency of the audio-modulating signal is changed. Thus, if the frequency of the modulation is held constant and the amplitude varied, the amount of energy radiated at the center or "carrier" frequency will vary through wide limits. The reason for this variation is that the modulation energy is distributed over the frequency spectrum; diversion of energy to "side current" frequencies takes center-frequency power. These variations in the center-frequency power can be calculated by means of **Bessel functions.** Ordinarily, they are plotted as a curve of amplitude against "modulation index" as shown below. The

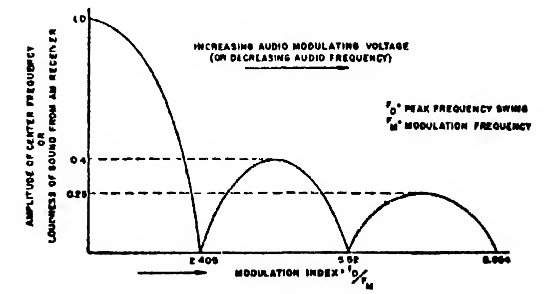


Diagram showing how the "Bessel-Zero" points may be found. As level of audio input is increased, the amplitude of the center frequency decreases and becomes zero when $F_d/F_m = 2.405$, 5.52, etc. (By permission from "The Radio Manual" by Sterling and Monroe, 4th Ed., Copyright 1950, D. Van Nostrand Co., Inc.)

"modulation index," which is the abscissa of the curve, is the ratio of the frequency swing (usually designated F_d) to the modulating frequency (usually designated F_m). It will be noted that the amplitude becomes zero at several points. The first point at which this occurs (when the audio-modulating voltage is increased upward from zero) is at the point

where the "modulation index" equals 2.405. If we can identify this point, and if we know the modulating frequency, we can figure how much "frequency swing" is occurring, because:

$$\text{Modulation index} = 2.405 = F_d/F_m.$$

Hence

$$F_d = 2.405F_m.$$

FREQUENCY - MODULATION PRODUCTION BY ARMSTRONG METHOD. A phase-shift modulation system developed by E. H. Armstrong, which modulates a carrier at very low level and frequency. The desired **carrier-frequency** and **deviation-ratio** is achieved by passing the signal through several frequency-multiplier amplifier stages. The low-level modulation is achieved by the use of a balanced modulator (see **modulator, balanced**) which has a quadrature carrier reinserted in its output.

FREQUENCY - MODULATION PRODUCTION BY REACTANCE TUBE METHOD. See **reactance tube.**

FREQUENCY-MODULATION, WESTINGHOUSE FREQUENCY CONTROL CIRCUIT. A pulse-controlled, **frequency-modulation system.**

FREQUENCY MONITOR. A device which gives a continuous indication of any departure of a **radio transmitter's** frequency from its assigned value.

FREQUENCY MONITOR, CRYSTAL. A device containing a highly-accurate, crystal-controlled **oscillator,** a stable, variable-frequency oscillator, and a **gridleak detector.** It may be used for checking unknown frequencies, and as a source of known frequencies.

FREQUENCY MULTIPLIER. A non-linear **network** or other device for generating **harmonics** of a sinusoidal input, and having means for selecting a certain harmonic as its output. (See also **transducer, harmonic conversion.**)

FREQUENCY, NATURAL. Of a body or system, a frequency of free oscillation. (See **oscillation, free.**) This term is commonly applied to coils and antennas in communication circuits. In the former it designates the frequency at which the inductance of the coil and its distributed capacity produce **resonance.** Referred to the antenna, it means the lowest frequency at which there will be a **standing wave** on the antenna.

FREQUENCY OF A PERIODIC QUANTITY. The frequency of a periodic quantity in which time is the independent variable, is the number of periods occurring in unit time. If a periodic quantity, y, is a function of the time, t, such that

$$y = f(t) = A_0 + A_1 \sin(\omega t + a_1) + A_2 \sin(2\omega t + a_2) + \cdots,$$

then the frequency is $\omega/2\pi$. Unless otherwise specified, the unit is the cycle per second.

FREQUENCY OF AMPLITUDE RESONANCE. The frequency of **maximum amplitude of oscillator.**

FREQUENCY OF ENERGY RESONANCE. For a forced harmonic oscillator the frequency for which the velocity and the energy dissipation of the system are maxima is given by

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

where k is the stiffness and m is the effective mass. (See **oscillation, forced.**)

FREQUENCY OF MAXIMUM AMPLITUDE OF OSCILLATOR. For a forced harmonic oscillator of effective mass m, the frequency for which the **amplitude** of the system is a maximum is given by

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m} - \frac{R}{2m^2}}$$

where k is the **force constant** and R is the **dissipative constant.** (See **oscillation, forced.**)

FREQUENCY, OPTIMUM WORKING. The most effective frequency at a specified time for **ionospheric propagation** of radio waves between two specified points. In predictions of useful frequencies, the optimum working frequency is commonly taken as 15 per cent below the monthly median value of the maximum usable frequency (see **frequency, maximum usable**), for the specified time and path.

FREQUENCY OVERLAP. In a color television system, that part of the frequency **band** which is common to the **monochrome channel**

and the **chrominance channel.** Frequency overlap is a form of band-sharing.

FREQUENCY PULLING. See **pulling figure.**

FREQUENCY PULSING. A phenomenon sometimes found in **oscillators** in which two likely frequencies of oscillation exist. As the oscillation at one frequency builds up, the electronic **admittance** developed by the tube may change in such a manner as to cause an oscillation at the second frequency to start building up which, in turn, may cause the first oscillation to cease. The oscillator may alternate between the two oscillation frequencies, or both may exist simultaneously.

FREQUENCY PUSHING. See **pushing figure.**

FREQUENCY RECORD. A recording of various known frequencies at known **amplitudes**, usually for the purpose of testing or measuring.

FREQUENCY RESPONSE. The range of frequencies passed with an allowable loss by a circuit or device, such as an **audio amplifier**, a **microphone** or a **loudspeaker.**

FREQUENCY RESPONSE CHARACTERISTICS OF THE EAR. The various response characteristics of the ear which depend on frequency. These include **loudness, pitch, masking, non-linearity of the ear, vibrato, timbre, auditory localization** and **minimum perceptible difference.**

FREQUENCY - RESPONSE EQUALIZATION (EQUALIZATION). The effect of all frequency discriminative means employed in a transmission system to obtain a desired over-all frequency response.

FREQUENCY SENSITIVITY. See **long-line effect.**

FREQUENCY SEPARATOR. The name sometimes applied to the circuits in a television receiver which separate the horizontal and vertical **synchronizing signals** from the **composite signal.**

FREQUENCY-SHIFT KEYING OR FSK. That form of frequency modulation (see **modulation, frequency**) in which the modulating wave shifts the output frequency between predetermined values, and the output wave is coherent with no phase discontinuity.

FREQUENCY, SIDE. One of the frequencies of a **sideband.**

FREQUENCY STABILIZATION. The process of controlling the **center frequency** so that it differs from that of a reference source by not more than a prescribed amount.

FREQUENCY STANDARD. The standard of frequency used in frequency measurement (see **frequency meter**), usually an extremely stable, crystal-controlled **oscillator.** The fundamental standard is the rotation of the earth, and other standards are checked against this. Standards which may be checked directly (by means of synchronous clocks) are called primary standards, while those which are checked against primary standards are called secondary standards.

FREQUENCY SWING. In frequency modulation (see **modulation, frequency**), the peak difference between the maximum and the minimum values of the instantaneous frequency.

FREQUENCY TRANSFER UNITS. A device consisting of a heterodyne **frequency meter** (with harmonic generating circuits) and a **heterodyne detector** which is utilized in transferring an unknown frequency for measurement against a **frequency standard.**

FREQUENCY TRANSLATION. Often in communication circuits it is desirable to move a frequency **channel** bodily to another part of the spectrum. This process is frequency translation and is performed by beating the frequencies to be moved with another fixed frequency. The sum or difference of the original frequencies and the beating frequency then gives the same channel at another point in the spectrum and by the proper choice of the beating frequency this new location can be fixed as desired.

FREQUENCY TOLERANCE OF A RADIO TRANSMITTER. The extent to which the **carrier frequency** of a **transmitter** may be permitted to depart from the frequency assigned.

FREQUENCY TRIPLER. A device delivering output voltage at a frequency that is three times the input frequency.

FREQUENCY, ULTRASONIC (SUPERSONIC FREQUENCY). A frequency lying above the audio frequency range. (See **fre-**

quency, audio.) The term is commonly applied to elastic waves propagated in gases, liquids, or solids. The word "ultrasonic" may be used as a modifier to indicate a device or system intended to operate at ultrasonic frequencies. The use of supersonic in this sense is deprecated, this modifier being used in connection with speeds higher than that of sound.

FRESNEL. A unit of **frequency** equal to 10^{12} cycles per second.

FRESNEL-ARAGON, LAW(S) OF. (1) Two rays of light polarized in the same plane interfere in the same manner as ordinary light. (2) Two rays polarized at right angles do not interfere. (3) Two rays polarized at right angles from ordinary light and brought into the same plane of polarization, do not interfere in the ordinary sense. (4) Two rays polarized at right angles (obtained from plane **polarized light**) interfere when brought into the same plane of polarization.

FRESNEL BIPRISM. See **prism, Fresnel biprism.**

FRESNEL COEFFICIENT OF DRAG. The ratio, according to Fresnel, of the velocity of the ether in a moving transparent medium to the velocity of the medium itself. Supposed to have the value $1 - (1/n^2)$ where n is the refractive index of the medium. Experimentally verified by the **Airy experiment**, but the explanation today rests on **relativity theory** rather than ether drag. (See also **Fizeau experiment.**)

FRESNEL DIFFRACTION. (1) The radiation field transmitted through an aperture in an absorbing screen at distances large compared to the wavelength, and to the dimensions of the aperture, and yet small enough to require consideration of the effect of the phase-differences between secondary wavelets, even along the normal to the screen. (See **Fraunhofer region, Fresnel region.**) (2) The **diffraction** effect obtained when either the source of the radiation or the observing screen or both are at a finite distance from the diffracting aperture or obstacle, that is, the wave fronts are spherical rather than plane as in the case of Fraunhofer diffraction.

FRESNEL EQUATIONS. Equations giving the intensity in each of the two polarization components of light in a less dense medium reflected at the surface of a more dense transparent medium.

Vibrations normal to the plane of the incident and reflected beams:

$$\frac{I}{I_0} = \frac{\sin^2(i - r)}{\sin^2(i + r)}.$$

Vibrations in the plane of the incident and reflected beams:

$$\frac{I}{I_0} = \frac{\tan^2(i - r)}{\tan^2(i + r)}.$$

These may be combined for normal incidence into the more familiar equation

$$\frac{I}{I_0} = \left(\frac{n - 1}{n + 1}\right)^2$$

for air as one medium.

FRESNEL EQUATIONS FOR METALLIC REFLECTION. For strongly absorbing materials like metals, the **index of refraction** n of the simple **Fresnel equation** should be replaced by its complex form

$$\bar{n} = n(1 - i\kappa),$$

where κ is the absorption index. Introducing this and multiplying by the complex conjugate gives for the reflection coefficient

$$R = \frac{(n - 1)^2 + n^2\kappa^2}{(n + 1)^2 + n^2\kappa^2}.$$

Note that when κ is very large, the reflection coefficient is nearly unity.

FRESNEL INTEGRAL. If the **error function**, for real values of the variable t, is separated into real and imaginary parts

$$\frac{1}{(1 + i)} \operatorname{erf}(t) = C(t) - iS(t).$$

The resulting real functions are the **Fresnel integrals**

$$C(t) = \int_0^t \cos\frac{\pi x^2}{2}\,dx$$

$$S(t) = \int_0^t \sin\frac{\pi x^2}{2}\,dx.$$

FRESNEL MIRRORS. Two plane mirrors almost, but not quite, in the same plane. Light from a **point source** or **slit** after re-

flection from the two mirrors will show interference bands in the region where the light reflected from one mirror overlaps the light reflected from the other mirror. (See Robertson, *Introduction to Optics*, page 150.)

FRESNEL REGION. In antenna terminology, the region between the antenna and the **Fraunhofer** region. If the antenna has a well-defined aperture D in a given **aspect,** the Fresnel region in that aspect is commonly taken to extend a distance $2D^2/\lambda$ in that aspect, λ being the wavelength.

FRESNEL RHOMB. A glass **rhomb** with acute angles of about 55 degrees. Plane-**polarized light** incident normally upon an end of the rhomb, with plane of vibration making an angle of 45 degrees to an edge of the rhomb, will emerge from the opposite end circularly-polarized. This is essentially true for all wavelengths, since the effect is the result of internal **total reflection.**

FRESNEL ZONES. The zones discussed in **diffraction, half-period elements.**

FREUNDLICH ADSORPTION ISOTHERM. See **adsorption isotherm.**

FRICTION. The resistance offered to the motion of one body upon or through another.

FRICTION, ANGLE OF. The angle whose tangent is equal to the coefficient of static friction. (See **friction, coefficient of static.**)

FRICTION BEARING. See **bearings, types of.**

FRICTION, COEFFICIENT OF KINETIC (SLIDING). For two surfaces, the ratio of the tangential force which is required to sustain motion without acceleration of one surface with respect to the other, to the normal force which presses the two surfaces together. It is generally less than coefficient of static friction.

FRICTION, COEFFICIENT OF STATIC. For two surfaces, the ratio of the maximum tangential force which is required initially to produce motion of one surface with respect to the other, to the normal force which presses the two surfaces together. It is generally greater than coefficient of kinetic friction. (See **friction, coefficient of kinetic.**)

FRICTION, CONE OF. A conical surface which always contains the resultant of the force of friction between two surfaces and the normal force pressing the two surfaces together. The half angle at the apex of the cone is equal to the angle of friction. (See **friction, angle of.**)

FRICTION LAYER. The lower layer of air, below the "free atmosphere," where friction with the earth's surface affects its flow. Depending upon conditions, its thickness is usually from 1500 to 3000 feet.

FRICTION, MECHANICAL. The chief causes of friction are the interlocking of the minute irregularities on the rubbing surfaces, adhesion between the surfaces, and the indentation of the softer by the harder body. Friction between solid bodies may be classified as sliding and rolling. The laws of sliding friction were investigated by Coulomb, who found that, approximately and within limits, (1) the friction between two surfaces is slightly greater just before motion begins than when the surfaces are in steady relative motion; (2) the friction is proportional to the force pressing the surfaces together; (3) it is independent of the area of contact, and (except at start) of the speed of relative motion. The constant ratio of the friction to the force pressing the surfaces together is called the coefficient of friction, some typical values of which are as follows:

Dry wood on dry wood	0.35
Leather on metal	0.55
Iron on stone	0.50
Wood on stone	0.40
Stone on stone or brick	0.65
Well-oiled metals	0.05

By means of such coefficients, it is possible to calculate what the friction will be between two bodies, as a wooden sill on a stone foundation, when the force pressing them together is given.

The tangent of the angle at which a plane surface must be inclined for a solid block to slide steadily down it is the coefficient of sliding friction between plane and block. Lubrication greatly reduces the coefficient by separating the solid surfaces Rolling friction, due to the indentation of the surfaces in rolling contact, is much less than sliding friction, as illustrated by the use of ball-bearings. The **viscosity** of liquids and gases is sometimes

called "internal friction," as is the dissipation of energy in a vibrating solid.

FRICTION, SLIDING. See **friction, coefficient of kinetic.**

FRICTION, STATIC. See **friction, coefficient of static.**

FRICTIONAL ELECTRICITY. See **triboelectrification.**

FRINGES, HAIDINGER. See **Haidinger fringes.**

FRINGES OF EQUAL INCLINATION. See **Haidinger fringes.**

FRINGE SHIFTS. See **Michelson interferometer.**

FRÖHLICH-BARDEEN THEORY. An attempt to explain **superconductivity** in terms of the interaction between the **conduction electrons** and the **lattice vibrations** of the metal. Formidable mathematical difficulties have prevented the completion of the theory (1955), but the **isotope effect** provides confirmation.

FRONT, FRONTOGENESIS, AND FRONTOLYSIS. Surfaces of discontinuity between **air masses** are called frontal surfaces. The intersections of these frontal surfaces with the surface of the earth are called fronts. Frontal surfaces are also loosely spoken of as fronts. Actually the discontinuity usually extends through a varying zone of transition which is known as the frontal zone. By convention the exact frontal surface is taken as the boundary between the warm air and the frontal zone. Frontogenesis is the formation or intensification of a frontal surface. Frontolysis is the disintegration or weakening of a frontal surface. Practically all frontal zones have clouds associated with them. Some are accompanied by precipitation. A great percentage of temperate-zone precipitation and weather is directly the result of frontal activity.

FRONT, COLD. A **front** along which colder air replaces warmer.

FRONT FOCAL LENGTH. The distance from the primary focal point to the front **vertex** of a lens. Its reciprocal is called the neutralizing power of the lens

FRONT, INTERTROPICAL. The boundary between the **trade wind** system of the northern and southern hemispheres. It manifests itself as a fairly broad zone of transition commonly known as the **doldrums.**

FRONT, OCCLUDED. A **front** along which a cold front overtakes a warm front. (See also **occlusion.**)

FRONT PORCH. In television, that portion of a **composite picture signal** which lies between the leading edge of the **horizontal blanking pulse,** and the leading edge of the corresponding **sync pulse.**

FRONT, QUASI-STATIONARY. The ideal stationary **front** is seldom found in nature, but it often occurs that the frontal movement is such that no appreciable displacement takes place. The front is then said to be quasi-stationary.

FRONT, SECONDARY. A second **front** of similar nature to and following fairly closely behind a primary front. A disturbance connected therewith is called a secondary disturbance.

FRONT, STATIONARY. A **front** along which one **air mass** does not replace the other.

FRONT-TO-REAR RATIO. In antenna terminology, the ratio of the effectiveness of a directional antenna (see **antenna, directional**) toward the front and toward the rear.

FRONT-WALL PHOTOVOLTAIC CELL. See **photovoltaic cell, front-wall.**

FRONT, WARM. A **front** along which warmer air replaces colder.

FROTH. A gas-in-liquid dispersion.

FROUDE NUMBER. The flow of an inviscid, incompressible fluid in two geometrically similar flow systems is dynamically similar if the Froude number of the two systems is the same. The number is defined as $V/(gl)^{1/2}$, where V is the velocity scale and l the length scale of the system considered, and g is the acceleration due to gravity. This criterion is only relevant if a free surface is present. Naval architects use an equivalent parameter, the speed-length ratio, defined as the quotient of the speed of the ship (or ship model) in knots divided by the square root of the length in feet.

FT. (1) Symbol for comparative lifetime. (See **lifetime, comparative.**) (2) Abbreviation for **foot** or feet.

FUCHS THEOREM. If a **second-order linear differential equation** has regular **singular points** at ∞ and at x_k, $k = 1, 2, \cdots, n$, and no other singularities, its general form is

$$y'' + \frac{p_{(n-1)}(x)y'}{F(x)} + \frac{p_{2(n-1)}(x)y}{F^2(x)} = 0$$

where $F(x) = (x - x_1)(x - x_2) \cdots (x - x_n)$ and $p_i(x)$ is a **polynomial** in x of degree $\leqq i$. Such an equation is said to be of **Fuchsian type.** The theorem may be extended to equations of any **order.**

FUGACITY. A quantity which measures the true **escaping tendency** of a gas, a sort of idealized pressure. If primes and double primes refer, respectively, to an ideal gas and a real gas, then $dG' = V'dp = RT\, d \ln p$, and $dG'' = V''dp = RT\, d \ln f$, where dG is a change in **free energy** or **chemical potential,** produced by a change in pressure, dp; V is the volume of the gas at the absolute temperature T, f is its fugacity and R is the gas constant.

FULGURATOR. An apparatus used in **spectroscopy,** consisting of an atomizer to spray salt solutions into a flame.

FULL-WAVE RECTIFIER(S). See entries under **rectifier, full-wave.**

FUME. Fine particles (0.2 to 1 micron in diameter) of a solid or liquid suspended in a gas; technically fumes are colloidal systems formed from chemical reactions like combustion, distillation, sublimation, calcination, and condensation.

FUNCTION. A mathematical expression describing the relation between variables; the function taking on a definite value, or values, when special values are assigned to certain other quantities, called the arguments, or independent variables of the function. If there is one independent variable, the dependent variable y may be determined by the equation $y = f(x)$; if there are several independent variables, by $y = f(x_1, x_2, \cdots, x_n)$. Functions may be classified in many ways, as: **explicit** or **implicit; continuous** or **discontinuous; algebraic** or **transcendental.** There are further subdivisions of these functions. Frequently a function is named in honor of a mathematician who discovered or studied it.

FUNCTION, CONTINUOUS. A function of one variable $f(x)$ is **continuous** at a value $x = c$ when $f(c)$ has a definite finite value which is equal to the limit of $f(x)$ when $x \to c$. A function is continuous in an interval (a,b) when it is continuous at every point of the interval, it being sufficient at the end points that

$$\lim_{x \to a^+} f(x) = f(a); \quad \lim_{x \to b^-} f(x) = f(b).$$

It has a **discontinuity** at a point where it is not continuous. The usual type of discontinuity is a point at which the function becomes infinite, or where it has a finite jump (also called a **saltus**).

Important properties of a continuous function are: (1) if it is continuous in a closed interval (a,b), then among the different values of $f(x)$ in this interval, there is a greatest value M and a least value m; (2) if its interval of continuity is (a,b), then between every two values x_1 and x_2 of x in this interval, $f(x)$ takes at least once every value between $f(x_1)$ and $f(x_2)$.

A function of two variables, $f(x,y)$, is continuous at a point (a,b) if

$$\lim_{\substack{x \to a \\ y \to b}} f(x,y) = f(a,b).$$

FUNCTION, CYLINDRICAL. See **Bessel differential equation.**

FUNCTION, ELLIPTIC. A **transcendental function,** defined as the inverse of an **elliptic integral.** It is a doubly-periodic function of the complex variable with no **singularities** except **poles** in the finite plane. Special forms of them are known as **Jacobi** and **Weierstrass elliptic functions.**

FUNCTION, EVEN. A **function** such that $f(x) = f(-x)$, typical examples being x^2 and $\cos x$. (See **function, odd.**)

FUNCTION, EXPLICIT. A **function** defined by a relation between the variables giving an equation expressing one variable directly in terms of the other without the necessity of solving the equation; for example, $y = f(x,z)$. (See also **function, implicit.**)

FUNCTION, HARMONIC. Any solution of the **Laplace equation** which has continuous

derivatives of first and second order. (See also **harmonic.**)

FUNCTION, HOMOGENEOUS. A function $f(x_1, x_2, \cdots, x_n)$ is **homogeneous** in all of its variables if, for any parameter t, $f(tx_1, tx_2, \cdots, tx_n) = t^n f(x_1, x_2, \cdots, x_n)$. The exponent n is the degree or order of the function. The behavior of such a function is known as the Euler theorem.

FUNCTION, IMPLICIT. A function defined by a relation between variables as $f(x,y,z) = 0$. (See also **function, explicit.**)

FUNCTION, INTEGRAL. Defined for a real or complex variable by a power series which **converges** for all finite values of the variable. This includes **polynomial functions** as special cases. An integral function may also be defined as a function of a **complex variable** which is **analytic** at all finite points of the complex plane. Simple examples, in addition to the polynomials, are the **exponential functions,** and the **trigonometric functions.**

FUNCTION, INVERSE. If $y = f(x)$ is a given **function** of x, then x regarded as a function of y is the **inverse function** of the given function. Examples of pairs of inverse functions are: the **square** of a variable and the **square-root function;** the **exponential** function and the **logarithmic** function; the **trigonometric** or **hyperbolic** functions and their **inverse** functions.

FUNCTION, LINEAR. A **polynomial** function of first degree in the variables. (See **equation, linear.**)

FUNCTION, MULTI-VALUED. See **branch point.**

FUNCTION, ODD. A **function** which changes sign when the sign of the dependent variable is changed: $f(-x) = -f(x)$. Typical examples are x^3 and $\sin x$. (See **function, even.**)

FUNCTION, PERIODIC. A **function** for which a constant a exists so $f(z) = f(z + na)$, where n is an integer. The function repeats itself periodically with the fundamental period a. Typical examples are $\sin z$, $\cos z$, with fundamental period 2π; e^z, with fundamental period $2\pi i$. Functions may be doubly periodic such that the periods are of the form $(na + n'a')$, both n and n' integers but not both zero. (See **elliptic functions; trigonometric functions; exponential functions;** etc.)

FUNCTION, STEP. A piece-wise constant function. For example, $f(x) = 0$ for $x < 0$ and $f(x) = 1$ for $x > 0$.

FUNCTION SWITCH. A **network** or system having a number of inputs and outputs, and so connected that signals representing information expressed in a certain code, when applied to the inputs, cause output signals to appear which are a representation of the input information in a different code.

FUNCTION SWITCH, ONE-MANY. A **function switch** in which only one input is excited at a time and each input produces a combination of outputs.

FUNCTION, TRANSCENDENTAL. A function which is not **algebraic.** The following include the more important types: **trigonometric functions, inverse trigonometric functions, exponential functions, hyperbolic functions, logarithmic functions, gamma functions, beta functions, elliptic functions, Bessel functions,** etc.

FUNCTION UNIT. A device which can store a functional relationship and release it continuously or in increments.

FUNCTION, UNIT SAMPLING. The synchronizing or gating **pulse-train** used in pulse-amplitude modulation systems. (See **modulation, pulse-amplitude.**)

FUNCTION, WEIGHTING. See **Sturm-Liouville equation.**

FUNCTIONAL. A **function** whose argument or independent variable is a curve or surface (or a corresponding function). It may also be described as a function of a function.

FUNDAMENTAL BAND. See **band, fundamental.**

FUNDAMENTAL COMPONENT. The fundamental frequency component in the **harmonic analysis of a wave.**

FUNDAMENTAL FREQUENCY. See **frequency, fundamental.**

FUNDAMENTAL MODE OF VIBRATION. See **vibration, fundamental mode of.**

FUNDAMENTAL PARTICLE. See **elementary particle.**

FUNDAMENTAL SERIES. See **series in line spectra.**

FUNDAMENTAL TONE. See **tone, fundamental.**

FUNICULAR POLYGONS AND CATENARIES. If a closed loop of cord or rope is pulled at several points by forces in various directions, it forms a figure, plane or otherwise, known as a funicular polygon. The external forces acting on the loop at the vertices are, for **equilibrium,** subject to the same conditions as a set of non-concurrent **forces** acting on a rigid body; while the three forces concurrent at each vertex, including the tensions in the loop itself, may be represented

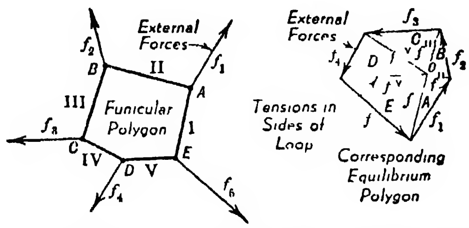


Fig 1 Closed funicular polygon with diagram of forces

by an equilibrium triangle, and the several triangles fitted together to form the equilibrium polygon for the external forces (Fig. 1). Fig 2 gives the corresponding analysis

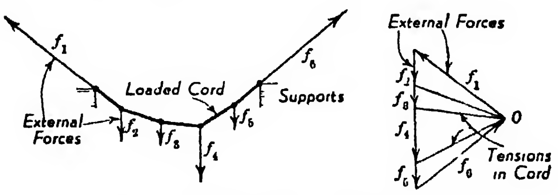


Fig 2. Suspended cable with unequal loads

for an open cord supported at the ends and loaded by weights hung vertically from it In Fig. 3 the weights are equal, have equal hori-

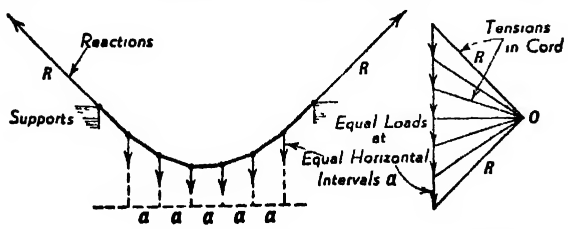


Fig. 3. Suspended cable with equal loads as in a suspension bridge

zontal spacing, and are hung close together. The form of the cord in this case approximates a parabola. This condition practically obtains with the cables of a suspension bridge. The point O in each figure is located by drawing from the extremities of any side of the external-face polygon lines parallel to the sides adjacent to the corresponding vertex of the funicular polygon.

If a suspended cord is loaded uniformly along its length (not horizontally), as by its own weight, it assumes the form of a **catenary.** The equation of this curve may be written

$$y = \frac{a}{2}\,(e^{x/a} + e^{-x/a}) = a \cosh \frac{x}{a}.$$

(The hyperbolic cosine form is convenient for numerical computations.) a represents the Y-intercept of the curve. It is an interesting property of a catenary cable that if at any

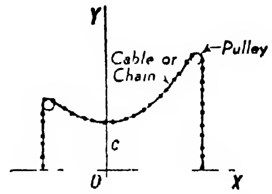


Fig 4 Tension of chain in catenary balances weight of chain hanging down to X-axis

point it is hung over a pulley, and enough cable cut off to reach down to the X-axis (Fig. 4), the weight of this portion will just sustain the tension on the other side of the pulley. The funicular-polygon theory is sometimes useful in solving equilibrium problems involving nonconcurrent forces.

FURRY THEOREM. The contribution to any process in **quantum electrodynamics** arising from an electron-positron **closed loop** which is connected to an odd number of photon lines, vanishes identically.

FUSE. A fuse is a common protective or circuit breaking device for low-voltage **electric circuits.** It is an over-current protector, and since the current must first heat the metal, there is a time delay in fuse "blowing" that is inversely proportional to the current. This characteristic is called "inverse time element." The ordinary fuse consists of a calibrated length of conductor whose resistance is so chosen that when a certain current through it

is exceeded, it fails to lose by radiation enough of the resistance heat to keep its temperature below melting.

FUSION. A change from the solid to the liquid phase of matter. In crystalline bodies, and, we are beginning to understand, also in many other solids not exhibiting well-defined **crystal structure,** the atoms are held in positions of stable equilibrium by intermolecular forces. They of course move with thermal agitation, but their movements are oscillatory and do not carry them outside a limited range of distance from their equilibrium positions. If a solid body is sufficiently heated, the molecules break loose from their stable configuration and wander about or diffuse among each other. When this condition has become general, the body exhibits the characteristics of a liquid, and we say it has undergone fusion. In some cases, such as ice, the change is quite abrupt, the substance having a well-defined **melting point;** in others, like glass or pitch, it is gradual The difference is probably due to the more uniform potential energy of the atoms in the former case, so that they all "break loose" at the same stage of thermal agitation; while in the latter case some atoms require more energy to dislodge them than others. In any case the process requires a supply of energy which is recognized as the **heat of fusion.** With most substances, fusion is accompanied by an increase in volume; but with some, like ice, the volume becomes definitely less.

FUSION, NUCLEAR. The combination of two light nuclei to form a heavier nucleus, with the release of the difference of the nuclear **binding energy** of the products and the sum of the binding energies of the two light nuclei. Examples are:

$$_1D^2 + {}_1D^2 \rightarrow {}_2He^3 + {}_0n^1 + 3.22 \text{ Mev},$$

$$_1D^2 + {}_3Li^7 \rightarrow {}_4Be^8 + {}_0n^1 + 15\ 1 \text{ Mev}.$$

Fusion reactions can take place only if the reacting nuclei possess sufficiently high energies to overcome their mutual Coulomb repulsion and to approach within the range of nuclear forces, hence they are favored by high temperatures. (See also **thermonuclear reaction, carbon cycle, proton-proton chain.**)

FUSION AS AN ORDER-DISORDER TRANSITION. The concept that fusion of a crystalline solid is essentially a change from the almost perfectly ordered solid state to a disordered liquid state The vacant spaces in the **crystal lattice** correspond to the other component in the binary alloys which undergo **order-disorder transition** in the pure form. Evidence from **X-ray diffraction** measurements indicates that **short-range order** is retained during fusion but **long-range order** is lost

FUTURE OF AN EVENT, ABSOLUTE. See **absolute future of an event.**

G

G. (1) Gram (g). (2) Gravitation acceleration (g), local gravitational acceleration (g_L), standard gravitational acceleration (g_0). (3) Acceleration of free fall (g). (4) Newtonian gravitational constant (G). (5) Electrical conductance (g or G). (6) Grid or input conductance (g_g), thus g designates the grid of a tube, either as a subscript or as a symbol on a circuit diagram. (7) Plate conductance (g_p). (8) Degeneracy (statistical weight) (g). (9) Modulus of shear elasticity (G). (10) Gibbs function (or free energy) (G, though F is also in common use). The Gibbs function per molecule or atom (g or g_m), per mole (G, g, or G_M), and per unit mass (g). (11) Gyromagnetic ratio (g). (12) Landé factor (g). (13) Transconductance, grid-plate (g_{pg} or g_m). (14) Coupling constant (g). (15) In spectroscopy, ghost (g). (16) Type of electron with an azimuthal quantum number of 4 (g). (17) Spectral term symbol for L-value of 4 (G). (18) Vibrational part of the energy of a molecule (G). The usage in (18) assumes separability of the energy into three parts, $T = T_e + G + F$, expressed in kaysers or megacycles.

G STRING. Colloquialism for a round, solid, dielectric-coated single wire used as a **waveguide** for the transmission of microwave energy. For many frequencies ordinary copper magnet wire coated with enamel or synthetic enamel may be employed. Also, a string tuned to the G-tone, as is the lowest string on a violin.

GADOLINIUM. Rare earth metallic element. Symbol Gd. Atomic number 64.

GAIN (TRANSMISSION GAIN). (1) A general term used to denote an increase in signal power in transmission from one point to another. Gain is usually expressed in decibels and is widely used to denote transducer gain. (See also **amplifier; antenna, directional.**) (2) The ratio of the output of a **transducer** to the input, even when these quantities are not measured in terms of power. Thus we refer to the voltage gain or current gain of an amplifier.

GAIN-BAND MERIT. The maximum band over which a matched **insertion** power-gain of unity (zero db) may be obtained in an **amplifier** stage.

GAIN-BANDWIDTH PRODUCT. The gain bandwidth product is equal to the product of **amplification** of an amplifier stage at midband, multiplied by the bandwidth of the amplifier in megacycles. The bandwidth is defined as the difference Δf between the two frequencies at which the power output is a specified fraction, usually one-half, of the midband (resonance) value. For a stage having a single resonant circuit (in its output) this product is found to be

$$\text{gain-bandwidth} = \frac{g_m}{2\pi(\Sigma C)} \text{ megacycles,}$$

where g_m is the transconductance (micromhos) of the stage and ΣC is the total capacitance (micromicrofarads) across the output.

GAIN, DIRECTIVE. See **directive gain.**

GAIN, INSERTION. See **insertion gain.**

GAIN MARGIN. In **feedback systems,** a stability criterion which indicates the increase in gain which would be required to cause **oscillation.** It is expressed as the reciprocal of the magnitude of the loop gain at the frequency where the phase shift is $-180°$.

GAIN OF ANTENNA. See **antenna, gain of.**

GALAXY NOISE. Noise with the same character as thermal-electronic noise which comes from the general direction of the Milky Way.

GALE. Wind with an hourly velocity exceeding some specified value. In the **Beaufort scale,** the various gale winds have velocities above 32 miles per hour.

GALILEAN RELATIVITY. Invariance of the equations of classical Newtonian dynam-

ics under a transformation to a coordinate system moving with constant velocity. Thus by no *mechanical* experiment in a laboratory could an observer measure the absolute velocity of the laboratory or its velocity relative to the "fixed stars."

GALILEAN TELESCOPE. A form of **telescope** which has a divergent lens for **ocular** and in which no real image is formed. The field of view is small, but the whole telescope is shorter than with conventional telescopes of comparable power. Commonly used in opera glasses.

GALILEAN TRANSFORMATION. The transformation to a system moving with constant relative velocity according to non-relativistic kinematics:

$$dx' = dx - v_x dt$$

$$dy' = dy - v_y dt$$

$$dz' = dz - v_z dt$$

$$dt' = dt.$$

GALL POTENTIOMETER. See **potentiometer, Gall.**

GALLIUM. Metallic element. Symbol Ga. Atomic number 31.

GALLON. A unit of liquid measure. The United States gallon is 231 cubic inches in volume. The imperial gallon used in England contains 277.46 cubic inches and is equivalent to 1.20032 U.S. gallons. The U.S. gallon of water weighs 8.345 pounds at 4°C and is divided into four quarts, 8 pints, or 128 fluid ounces.

1 U.S. gallon = 3.78543 liters.
1 imperial gallon = 4.54345 liters.

GALVANOLUMINESCENCE. See **luminescence.**

GALVANOMETER. An instrument for measuring electric currents, usually by means of their magnetic effect. Observations are made by noting the deflection produced by the **torque** exerted between an **electric circuit** and a magnet. Galvanometers may be divided broadly into two classes, according to whether the coil is stationary and the magnet turns, or vice versa.

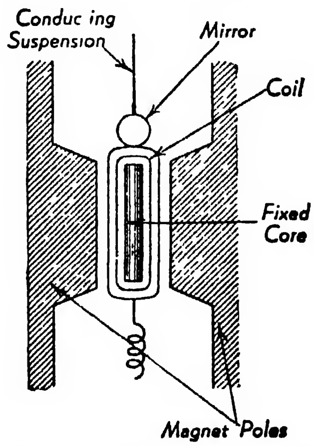
Perhaps the most highly developed of the first type is the Kelvin astatic galvanometer (see **galvanometer, Kelvin astatic**). Among galvanometers of the second type, the best known is the d'Arsonval galvanometer (see **galvanometer, d'Arsonval**). There are also string galvanometers, in which a straight, slender wire carrying the current is thrust to one side by the magnetic field; and vibration galvanometers in which the string vibrates in synchronism with the alternating current traversing it.

GALVANOMETER, ASTATIC. A galvanometer which gives readings independent of the earth's magnetic field by means of a construction feature in which readings of current are obtained by passing the current through a coil around a system of two movable needles with opposing magnetic fields.

GALVANOMETER, BALLISTIC. A galvanometer which is used most commonly to measure the total quantity of electricity in a transient current, and is accordingly designed to have a long period of swing (high moment of inertia) of its moving element.

GALVANOMETER CONSTANTS. The performance of a **galvanometer** can be described in terms of either of two sets of constants. The structural constants are: moment of inertia, damping, torsion constant, and motor constant. The behavior or working constants are: sensitivity, galvanometer resistance, critical damping resistance, and free period. The values of either set of constants are derivable from those of the other set.

GALVANOMETER, D'ARSONVAL. A moving-coil galvanometer in which the magnet is a fixed, permanent magnet of the horseshoe



Essential parts of D'Arsonval galvanometer

or double-horseshoe form, with a light, rectangular coil suspended in the strong field between its poles, the suspension carrying the feeble current. The current causes the coil to turn in the field. Often a fixed iron core is supported inside the movable coil to concentrate the field.

If these galvanometers are undamped, they will give a "throw" when a charge of electricity is sent through them, and the charge can be thereby measured. Such an instrument, with a heavy coil, called a ballistic galvanometer, is useful in capacitance meaurements. The oscillations may be damped by shunting.

GALVANOMETER, EINTHOVEN. A string galvanometer (see **galvanometer, string**) which is made very sensitive by the use of a strong magnet and a fine quartz or metallic thread, whose movement is observed optically.

GALVANOMETER EQUATION. The equation of motion of a **galvanometer:**

$$P\frac{d^2\theta}{dt^2} + \left(K + \frac{G^2}{R}\right)\frac{d\theta}{dt} + U\theta = \frac{GE}{R},$$

where P is the moment of inertia, K, the mechanical damping coefficient, U, the restoring torque constant, G, the motor constant, E, the applied voltage and R, the total circuit resistance. (See **galvanometer constants.**)

GALVANOMETER, KELVIN ASTATIC. A stationary-coil **galvanometer** which has two magnets equally magnetized but antiparallel, mounted on the same suspension, one above the other, and each magnet is surrounded by a coil. The two coils are joined in series and are oppositely wound, so that a current through them will turn their respective magnets in the same direction. The earth's uniform field has no effect upon such an astatic pair of magnets; but there is a large control magnet, placed above the pair, against whose field the current turns the suspended system. The movement is observed by the usual mirror-and-scale or optical lever device. Galvanometers of this type are now nearly obsolete.

GALVANOMETER, MIRROR. Any **galvanometer** in which the deflection is measured by the motion of a light-beam reflected from a mirror attached to the galvanic element.

GALVANOMETER, MOVING-COIL. A **galvanometer** in which a current-carrying coil is deflected by a fixed magnetic field.

GALVANOMETER, OSCILLOGRAPH. A d'Arsonval galvanometer (see **galvanometer, d'Arsonval**), for use in a mechanical-deflection **oscillograph.**

GALVANOMETER RECORDER. A combination of mirror and coil suspended in a magnetic field. The application of a signal voltage to the coil causes a reflected light beam from the mirror to pass across a slit in front of a moving photographic film, thus providing a photographic record of the signal. Other galvanometer recorders use a photoelectric system so arranged that the motion of the mirror drives a "slave coil" which carries a pen and records the magnitude of the signal on a moving paper chart.

GALVANOMETER, STRING. A fixed-magnet **galvanometer,** in which a straight, slender wire carrying the current is thrust to one side by the magnetic field.

GALVANOMETER, TANGENT. A **galvanometer** in which the sensing element is a magnetic needle pivoted at the center of a thin circular coil. In equilibrium, the needle points in the direction of the vector resultant of (1) the earth's magnetic field, and (2) of the magnetic field produced by the current in the coil.

GALVANOMETER, VIBRATION. A **galvanometer** in which a straight, slender wire in the field of a magnet vibrates in synchronism with the frequency of the alternating current traversing it. Vibration galvanometers ordinarily operate at a fixed frequency, and include provision for the tuning of the moving system to resonance at this frequency.

GALVANOMETRY. The art and process of detecting and measuring the strength of electric currents.

GAMMA. (1) The one-millionth part of a gram. (2) A unit of **magnetic field intensity.** (3) The tangent of the angle of the straight-line portion of the D log E curve and the log E axis is a measure of the degree of development and was termed by Hurter and Driffield the *development factor* and designated

by the Greek letter γ (gamma). Gamma may also be defined as

$$\gamma = \frac{D_2 - D_1}{\log E_2 - \log E_1}$$

where D_2 and D_1 are **densities** on the straight-line portion of the D log E curve produced by log E_2 and log E_1, respectively, and where E_2 and E_1 are exposures (see **exposure, photographic;** also **exposure-density relationship**). (4) In a color or monochrome television channel, or part thereof, the coefficient expressing the selected evaluation of the slope of the used part of the log vs. log plot relating input (abscissa) and output (ordinate) **signal magnitudes** as measured from the point corresponding to some reference **black level.** As the log vs. log plot is usually not entirely straight in the used region, it is necessary to formalize that evaluation of the slope, for example, by the use of the value at a particular point, maximum, mean, or other value. The method of evaluation should be stated. At some points, the signal may be in terms of **light intensity** or **light transmission.**

The letter gamma is also used as a symbol for: (A) Activity coefficient, molal basis (γ). (B) Specific weight or weightivity (γ). (C) Ratio of specific heats of a gas (γ). (D) Angular magnification (γ). (E) Surface tension (γ). (F) Permeance (Γ). (G) Propagation constant (γ). (H) Gruneisen constant (γ).

GAMMA CORRECTION. The modification of a **transfer characteristic** for the purpose of changing the value of gamma. (See **gamma (4).**)

GAMMA FUNCTION. The **infinite integral,** sometimes called **Euler's second integral**

$$\Gamma(z) = \int_0^\infty e^{-t}t^{z-1}dt.$$

It **converges** for all positive values of z. Its properties include:

$$\Gamma(z+1) = z\Gamma(z); \quad \Gamma(z)\Gamma(1-z) = \pi \csc \pi z;$$

$$\Gamma(\tfrac{1}{2}) = \sqrt{\pi}; \quad \Gamma(n) = (n-1)!,$$

when n is a positive integer.

The Weierstrass definition of the function is

$$\frac{1}{\Gamma(z)} = ze^{Cz}\prod_{n=i}^{\infty}\left(1+\frac{z}{n}\right)e^{-z/n}$$

where C is the **Euler-Mascheroni constant;**

$$C = \lim_{n\to\infty}\left(1+\tfrac{1}{2}+\cdots+\frac{1}{n}-\ln n\right)$$
$$= 0.5772\cdots.$$

Another definition is that of Euler

$$\Gamma(z) = \lim_{n\to\infty}\frac{(n-1)!}{z(z+1)\cdots(z+n-1)}n^z.$$

GAMMA RAY. A quantum of electromagnetic radiation emitted by a nucleus as a result of a quantum transition between two **energy levels** of the nucleus. Gamma ray energies range from 10^4 to 10^7 ev, with correspondingly short wavelengths and high frequencies, and their ability to penetrate matter is high. They follow transitions that leave the product nuclei in excited states, as well as in many induced **nuclear reactions** and **isomeric transitions.**

GAMMA-RAY EMISSION, MEASURE OF. The International Commission on Radiological Units (July 1953) recommended that γ-ray emission be expressed in terms of **roentgens** per **millicurie-hour** at 1 centimeter from point source. This quantity is different for every radionuclide.

GAMMA-RAY ENERGIES, DETERMINATION OF. The most direct procedure is to determine the wavelength, hence the frequency, by using a crystal as a **diffraction grating.** Other methods are to measure the energy of **photoelectrons, Compton recoil electrons, electron-positron pairs** or the absorption of γ-rays in matter.

GAMMA RAY SPECTRUM. One or more sharp lines each corresponding to an intensity and energy characteristic of the source. The term is sometimes applied to x-ray photons and **annihilation radiation** photons, having high energies in the γ-ray range, but which differ from γ-rays in their origin.

GAMOW-TELLER SELECTION RULES. See **selection rules, Gamow-Teller.**

GAP, AIR. See **air gap.**

GAP FACTOR OR MODULATION COEFFICIENT. In **traveling-wave tubes,** the ratio of peak energy gained (electron volts) to the peak resonator voltage.

GAP LENGTH. In longitudinal magnetic recording, the physical distance between adjacent surfaces of the poles of a **magnetic head.** The effective gap length is usually greater than the physical length and can be experimentally determined in some cases.

GAP, MAIN (OF A GLOW-DISCHARGE COLD-CATHODE TUBE). The conduction path between a principal cathode and a principal anode.

GAS. A state of matter, in which the molecules move freely, and consequently the entire mass tends to expand indefinitely, occupying the total volume of any vessel into which it is introduced. Gases follow, within considerable degree of fidelity, certain laws relating their conditions of pressure, volume, and temperature (see **equations of state**); they mix freely with each other; and they can all be liquefied.

GAS AMPLIFICATION. (1) A property of a gas-filled radiation **counter tube,** defined by the formula $V = Ane/C$. Here the gas amplification (A in the formula) is the number of additional ions produced by each electron produced in the **primary ionizing event,** as it travels to the central wire in a radiation **counter.** The formula expresses the size of the pulse V in volts appearing in the counter in terms of the gas amplification A, the number of electrons formed in the initial ionizing event n, the electron charge in microcoulombs, e, and the distributed capacity of the central wire system in microfarads, C. (2) In a gas **phototube,** the ratio of **radiant** or **luminous sensitivities,** with and without ionization of the contained gas, is the gas amplification factor.

GAS BALANCE. An instrument for measuring the density of a gas. Regnault used a globe or "balloon" which was filled with gas and weighed, its weight when evacuated being known. The Whytlaw-Gray microbalance is a delicate "buoyancy" apparatus.

GAS CLEANUP. See **cleanup.**

GAS CONSTANT. The constant of proportionality R in the equation of state of a perfect gas $pv = RT$, when referring to one gram-molecule of gas. R has the value of 1.985 calories per mole degree (C°).

GAS(IONIZATION) CURRENT (IN A VACUUM TUBE). Current flowing to a negatively-biased electrode, and composed of positive ions which are produced by an **electron current** flowing between other electrodes. Positive ions are a result of collision between electrons and molecules of the residual gas.

GAS DISCHARGE. See **discharge, gaseous.**

GAS DISCHARGE, FIELD-INTENSIFIED. See **gas discharge, nonself-maintaining.**

GAS DISCHARGE, NONSELF-MAINTAINING. A **conduction current** in a gas which is due to ionization of the gas from an external source other than the applied voltage. Also known as a **field-intensified discharge** or a **Townsend discharge.**

GAS DISCHARGE. SELF-MAINTAINING. **Ionic conduction** in a gas caused by the application of an electric field sufficient to cause creation of the necessary supply of ions by collisions between electrons and molecules. Breakdown may be due to an external ionizing source, but once the discharge is initiated it will continue unaided.

GAS ELECTRODE. See **electrode, gas.**

GAS-FILLED COUNTER TUBE. See **counter tube, gas-filled.**

GAS FOCUSING. A method of concentrating an **electron beam** by the action of ionized gas. The positive ions produced in the gas compensate for the negative **space charge** of the electrons.

GAS, IDEAL. The theoretical concept of a gas whose molecules have mass but no finite size, and do not exert forces upon each other.

GAS, INERT. A gas that does not react chemically, such as **helium, argon, neon, krypton,** and **xenon.**

GAS MAGNIFICATION. See **gas amplification.**

GAS MANOMETER. A pressure gauge used for gases.

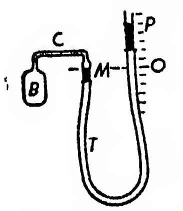
GAS NOISE. Noise caused by the random production of ions in **gas tubes** and partially-evacuated **vacuum tubes.**

GAS, PERMANENT. **Oxygen, nitrogen, hydrogen,** and other gases which require low temperatures for their liquefaction. In the

early days of scientific investigation, before methods had been developed for obtaining these conditions, it was believed that these gases could not be liquefied at all, and hence they were called "permanent" gases.

GAS RATIO. The ratio of the **ion current** in a vacuum tube to the **electron current** that produces it.

GAS THERMOMETER. When the standard measure of **temperature** was fixed upon as the pressure of a gas kept at constant volume, the constant-volume gas thermometer became the final arbiter of temperature measurement (see **thermometry**). In this instrument the gas (preferably hydrogen or helium) is enclosed in a glass or fused quartz bulb that is connected to a mercury manometer, and facilities are provided to bring the gas always to the same volume and to indicate the gas pressure. The most common form, designed by Jolly (1874), is shown diagrammatically by the figure, in which *B* represents the bulb, *T* the flexible tube of the manometer, *M* the constant-volume mark at zero level, and *P* the level of the mercury indicating the pressure. The pressure is regulated by moving the right-hand mercury column up or down the scale. Slight corrections are necessary for the expansion of the bulb and for the difference of temperature between the gas in the bulb and that in the connecting tube *C*.



Sketch of essential parts of constant-volume gas thermometer

GAS TUBE. An **electron tube** in which the pressure of the contained gas or vapor is such as to affect substantially the electrical characteristics of the tube.

GAS TURBINE. In the gas turbine a stationary nozzle discharges a jet of gas (usually products of combustion) against the blades on the periphery of a turbine wheel. The jet is thereby deflected and slowed while the blades receive an impulse force which is transmitted as a mechanical torque to the shaft. The prospective jet speed is sometimes sufficiently high to warrant dividing the expansion into a series of *stages* with a set of nozzles and a row of blades in each stage, all blade wheels being mounted on the same shaft. By limiting the gas expansion per stage the blade speed and rpm of the shaft are suitably decreased. Were the blades themselves so shaped as to be virtual nozzles, some expansion would also take place in the gas as it went through the blading. The latter in consequence would receive a "reaction thrust" distinct from impulse action. Many gas turbine designs have employed the reaction principle.

A properly designed nozzle can produce almost an ideal (isentropic) adiabatic expansion of the gas. Any failure of the gas turbine to convert all the ideal available energy into work at the shaft is mainly attributable to the blading—its clearance, friction, leakage, and residual gas velocity.

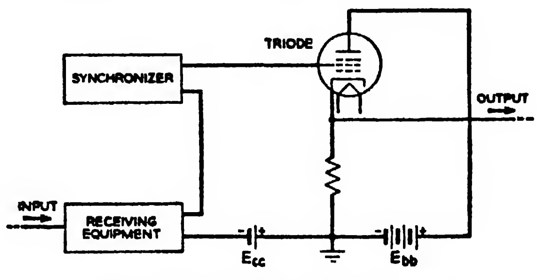
GAS, TWO-DIMENSIONAL. A layer of adsorbed gas, of monomolecular thickness.

GASEOUS TUBE GENERATOR. A power source comprising a gas-filled **electron tube oscillator,** a power supply, and associated control equipment.

GATE. (1) A circuit having an output and a multiplicity of inputs so designed that the output is energized when and only when a certain definite set of input conditions are met In computer work, a gate is often called an "and" circuit. (2) A signal used to enable the passage of other signals through a circuit. (3) That part of a saturable reactor which exhibits **thyratron or gate action.**

GATE ANGLE (FIRING ANGLE). The angle at which the **gate impedance** changes from a high to a low value. This angle is also called the firing angle.

GATE CIRCUIT. A circuit which amplifies or passes a signal only in the presence of an appropriate synchronizing or "gating" pulse which "opens the gate." The following circuit is a simplified example of one form which gating circuits may take:



Simplified drawing of gate circuit

In this circuit, pulses from the receiving equipment are combined with rectangular

pulses from the **synchronizer,** and impressed upon the grid of a triode along with a negative, biasing voltage. Pulses from the synchronizer are of positive-polarity, and sufficiently large to cause the triode to operate in its **linear mode** when they are present. When synchronizing pulses are absent, the triode is cut off, and the output is zero.

Several gate circuits may merge into the load; the latter circuit is then called the load circuit, and the total current flowing through the load is called the load current.

GATE CIRCUIT A-C SUPPLY VOLTAGE. The a-c voltage source appearing in the gate circuit of a **magnetic amplifier,** the function of which is to drive the **saturable reactor** core flux from the present level to saturation. In general this voltage source is also the load voltage source and supplies power to the load during conducting intervals of the cycle

GATE CURRENT. The current flowing in the **gate winding.**

GATE IMPEDANCE. The impedance of one **gate winding.**

GATE RESISTANCE. The resistance of one **gate winding.**

GATE, TIME. See **time gate.**

GATE VOLTAGE. The voltage across the terminals of the **gate winding.**

GATE WINDING. The winding of a **saturable reactor** which produces the "on-off" action on the load current.

GATED-BEAM TUBE. Essentially a **pentode** with a very sharp cut-off and maximum anode current. This sharp transition is achieved with the aid of fixed-potential electrodes, which form a sheet beam of electrons, which may be deflected away from the anode by the application of a relatively small voltage to a control electrode.

GATING. (1) The process of selecting those portions of a wave which exist during one or more selected time-intervals, or which have magnitudes between selected limits. (2) The function or operation of a **saturable reactor** or **magnetic amplifier** which causes it, during the first portion of the conducting alteration of the a-c supply voltage to block substantially all of the supply voltage from the load; and during latter portion allows substantially all of the supply voltage to appear across the load; is called gating or gating action. The "**gate**," is said to be virtually closed before firing and substantially open after firing.

GATING CIRCUIT. A time-selection transducer. (See **transducer, time-selection.**)

GATING HALF-CYCLE. The half-cycle of the supply voltage during which **gating** takes place and a **gate current** may flow.

GATING WAVEFORM. A waveform (sometimes called the "gate") applied to the control point of a circuit in such a way as to alter the mode of operating of the circuit while the waveform is applied.

GAUGE. An instrument or device for comparing some physical characteristic, such as size, pressure, temperature, water level, force, radiation intensity, etc. (See, for example, **pressure gauge.**)

GAUGE, ALPHATRON. An ionization gauge (see **gauge, ionization**) in which the ionization is produced by α-particles obtained from a radioactive source, instead of by electrons emitted from a hot filament. It is useful at pressures above 10^{-3} mm Hg, where filament life is seriously shortened by positive-ion bombardment, chemical reaction with the residual gas, etc.

GAUGE, BAYARD AND ALPERT. An ionization gauge (see **gauge, ionization**) in which the ion collector consists of a fine wire located along the axis of a helical grid functioning as anode. In this manner photo-electron emission from the collector caused by soft x-rays originating in the anode is reduced, and lower pressures may be read.

GAUGE, BELLOWS. A pressure gauge in which the expansion and contraction of a flexible metal bellows is transmitted to an optical lever, a high sensitivity being achieved by the use of multiple reflections It can be used for the measurement of pressure differences as small as 2×10^{-3} mm Hg at any level of pressure, from vacuum up to several atmospheres.

GAUGE, COPLEY, PHIPPS and GLASSER. A form of ionization gauge (see **gauge, ionization**) in which a metal deposit on the inside of the glass envelope is used as ion collector.

GAUGE, DUSHMAN AND FOUND. A form of ionization gauge (see **gauge, ionization**) in which the grid (ion collector) is geometrically outside the anode. Electrons oscillate between the filament and grid before striking the anode and with their longer path length is associated a correspondingly greater probability of ionization.

GAUGE, EDWARDS. An ionization gauge (see **gauge, ionization**) in which a platinum-alloy ribbon filament containing barium and strontium metal is used as a source of electrons.

GAUGE, FIBER. A pressure gauge in which the rate of damping of the vibrations of a fiber of some suitable material is used as a measure of pressure If the pressure is sufficiently low for the **mean free path** to be large compared with the thickness of the fiber, and the gauge is at a given temperature, then

$$p\sqrt{M} = \frac{A}{t} + B$$

where M is the molecular weight of the gas, A and B are constants characteristic of the fiber, and t is the time it takes for the amplitude of the vibration to fall to a given fraction of its initial value.

GAUGE, FOGEL. An ionization gauge (see **gauge, ionization**) in which the source of electrons is an oxide-coated ribbon filament of hairpin form placed symmetrically between two parallel plates of nickel, one of which serves as anode, the other as ion collector. A shield is provided near the base of the wire supporting the ion collector to insure that part of the glass surface between this wire and the other supports shall be kept free from any deposit of metal distilled from the electrodes. The leakage resistance is thus kept very high, allowing pressure readings down to 10^{-8} mm Hg.

GAUGE, FRYBERG AND SIMONS. A form of radiometer gauge (see **gauge, radiometer**) in which the leaf is made rigid and is hung from a wire, the ends of which are pivoted so that the leaf moves without distortion.

GAUGE, GAS DISCHARGE. A gauge in which the appearance of a gas discharge gives an indication of the pressure of the system. It is used for a variety of measurements in physics and related fields.

GAUGE, HALE. A Pirini gauge (see **gauge, Pirini**) in which the thermal contact at all supports is definite, thus eliminating a common source of error in gauges of this type.

GAUGE, HUNTOON AND ELLETT. An ionization gauge (see **gauge, ionization**) in which all three electrodes are in the form of tungsten spirals, each mounted at the ends on two current leads. It permits degassing of the individual elements by passing a current directly through them.

GAUGE INVARIANCE (FIRST KIND). Property that a **Lagrangian** describing a field ψ should be invariant under the transformation $\psi \rightarrow \psi e^{is}$ (where s is a real constant). The charge-conservation law follows from this property.

GAUGE INVARIANCE (SECOND KIND). The property of the **Maxwell equations** of being invariant under the transformation

$$A_\mu \rightarrow A_\mu + \frac{\partial \chi}{\partial x_\mu},$$

where A_μ is the potential **four-vector** and $\Box\chi = 0$ ($\Box$ = **d'Alembertian**). (See **field theory, Weyl unified.**)

GAUGE, IONIZATION. A gauge in which the rate of collection of positive ions on one electrode of a **triode** vacuum tube is used as a measure of the residual gas pressure in the tube.

GAUGE, KNUDSON LEAF. An early form of radiometer gauge (see **gauge, radiometer**) in which the construction is similar to that of a gold-leaf **electroscope.**

GAUGE, LANDER. An ionization gauge (see **gauge, ionization**) in which, by the use of two ion collectors of different sizes, it is possible to overcome to a large extent the limitation on sensitivity arising from **photoelectron** emission from the collector.

GAUGE, LOCKENVITZ LEAF. A leaf (radiometer) gauge (see **gauge, radiometer**) adapted particularly for use in kinetic metal vacuum systems. The aluminum leaf is suspended between adjacent parallel plane faces of copper jackets, in one of which steam is circulated, while the other is kept cool by tap water.

GAUGE, MAKINSON AND TREACY. An ionization gauge (see **gauge, ionization**) in which the ion collector is thin coating of Aquadag graphite on the cylindrical tube-wall, the anode is a wire along the axis, and the tungsten filament is near the collector and parallel to the axis. The electron paths are lengthened by the application of an axial magnetic field.

GAUGE, "MEMBRANE" OR "SURFACE." A pressure gauge in which the rate of damping of the vibrations of a very thin, light silica membrane is used as a measure of pressure. (See **gauge, fiber.**)

GAUGE, MORSE AND BOWIE. An ionization gauge (see **gauge, ionization**), the chief features of which are an ion collector consisting of a thin deposit of platinum over a portion of the inner wall of the tube, a hairpin tungsten filament, and a double spiral tungsten anode. It has a high sensitivity, attributed to the relatively larger volume between the anode and ion collector and to the open nature of the anode.

GAUGE, MULTIPLYING. A liquid **manometer** arranged so that the movement of an interface caused by a pressure difference is much greater than the head of liquid that would produce the pressure difference Common examples are the inclined tube manometer, and two-fluid manometers such as the **Chattock gauge.**

GAUGE, NELSON HYDROGEN. A gauge consisting of an evacuated and sealed-off ionization manometer connected to a vacuum system, via a heated palladium tube. The palladium allows hydrogen to pass through it, but no other gas, so that the device is useful as a leak detector. When hydrogen is introduced into the vacuum system at the leak, the pressure in the gauge increases.

GAUGE, PIRANI. A gauge in which the part of the energy lost by a heated wire which is due to conduction by the residual gas is taken as a measure of the pressure. When a wire, heated by a current, is in equilibrium, it loses heat (a) by radiation, (b) by conduction to the ends and other supports, and (c) on account of the fact that, on the average, molecules of residual gas colliding with or condensing on it leave it (on rebounding or re-evaporating) with a greater kinetic energy than that with which they arrived. If the **mean free path** of the molecules is not too small compared with the distance between the filament and the walls of the vessel, the energy loss under item (c) is, for a given gas and filament temperature, proportional to the pressure. Items (a) and (b) are functions of the filament temperature only.

A Pirani gauge in practice might consist of a tantalum lamp, the filament of which forms one arm of a **Wheatstone bridge.** The change in resistance due to cooling by the gas is then a measure of the gas pressure.

GAUGE, RADIOMETER. A pressure gauge in which the repulsion between adjacent hot and cold plates in an enclosure in which the residual gas molecules have a **mean free path** large compared with the distance between the plates is a measure of the pressure. It can be shown that subject to certain simplifying approximations the pressure is given by:

$$p = \frac{2f}{\sqrt{\frac{T_1}{T_2}} - 1}$$

where f if the repulsive force per unit area between the plates, and T_1 and T_2 are the absolute temperatures of the hot and cold plates, respectively In practice, because of the approximations inherent in the formula, the gauge is calibrated against a McLeod gauge. (See **gauge, McLeod.**)

GAUGE, WERNER LEAF. A leaf gauge in which a leaf of gold, silver or aluminum foil, 3–6 cm long, is suspended along the axis of a vertical glass tube to which are applied externally, opposite the two faces of the leaf, two well-fitting water jackets maintained at different temperatures.

GAUGE, WILLIAMS. A form of leaf gauge in which the hot surface is one face of a heated massive copper block, mounted opposite one side of an aluminum vane.

GAUSITRON. A **mercury-arc rectifier-tube** which utilizes a high-voltage arc for starting.

GAUSS. The emu unit of **magnetic induction (flux density)**, one **maxwell** per square centimeter.

GAUSS ERROR FUNCTION. See **error function.**

GAUSS EYEPIECE. A **Ramsden eyepiece** which has a thin plate of glass at 45° to the optical axis placed between the two lenses. Useful in setting a telescope normal to a plane-reflecting surface.

GAUSS HYPERGEOMETRIC EQUATION. A **canonical** form of the **Riemann-Papperitz equation,** where the **regular singular points** have been shifted to $x = 0, 1, \infty$. Its form is

$$x(1 - x)y'' + [\gamma - (\alpha + \beta + 1)x]y' - \alpha\beta y = 0$$

in which α, β, γ are parameters related to the exponents of the equation. Its general solution around the point $x = 0$ and convergent for $|x| < 1$, provided r is not a positive or negative integer or zero, is

$$y = AF(\alpha, \beta, \gamma; x) + Bx^{1-\gamma}F(1 + \alpha - \gamma, 1 + \beta - \gamma, 2 - \gamma; x).$$

In this solution $F(x)$ is the **Gauss hypergeometric function** and A, B are constants of integration.

GAUSS HYPERGEOMETRIC FUNCTION. A series solution of the **Gauss hypergeometric equation,**

$$F(\alpha, \beta, \gamma; x) = \frac{\Gamma(\gamma)}{\Gamma(\alpha)\Gamma(\beta)} \sum_{n=0}^{\infty} \frac{\Gamma(\alpha + n)\Gamma(\beta + n)}{\Gamma(\gamma + n)n!} x^n$$

where Γ is the **gamma function.** The coefficient of the general term x^k is

$$\frac{\left\{\begin{matrix}\alpha(\alpha + 1)(\alpha + 2) \cdots \\ (\alpha + k - 1)\beta(\beta + 1) \cdots (\beta + k - 1)\end{matrix}\right\}}{\gamma(\gamma + 1) \cdots (\gamma + k - 1)k!}.$$

Many well-known functions, including the **Legendre** and other **polynomials** are compactly represented by the hypergeometric series. Thus $F(1, \beta, \beta; x)$ is the ordinary **geometric series** and $F(\alpha, \beta, \beta; x)$ is the **binomial expansion** of $(1 - x)^{-\alpha}$.

GAUSS LAW. The total electric flux from a charge q is

$$\int \mathbf{D} \cdot d\sigma = \int \epsilon\mathbf{E} \cdot d\sigma = \int \frac{q}{r^2}\mathbf{r}_1 \cdot d\sigma = 4\pi q$$

for any surface enclosing the charge. For distributed charge of density ρ,

$$\int \mathbf{D} \cdot d\sigma = 4\pi \int \rho d\tau$$

or in differential form

$$\nabla \cdot \mathbf{D} = 4\pi\rho$$

by applying the Gauss theorem. (See **induction, electric.**) The above expressions are appropriate in all unrationalized systems. In rationalized systems, the factor 4π is replaced by unity.

GAUSS LAW FOR A MAGNETIC MEDIUM. Applying the **Gauss law** to the magnetic case:

$$\int \mathbf{B} \cdot d\sigma = 4\pi \int \rho dT$$

$$\nabla \cdot \mathbf{B} = 4\pi\rho$$

where **B** is the **magnetic induction,** and ρ the density of magnetic charge. Since free magnetic charge does not exist in nature, $\rho = 0$, and the Gauss law states:

$$\int \mathbf{B} \cdot d\sigma = 0$$

$$\nabla \cdot \mathbf{B} = 0.$$

GAUSS LAW OF NORMAL GRAVITATIONAL FORCE. The surface integral of the normal component of the gravitational force on a particle of unit mass, taken over any closed surface is equal to $-4\pi G$ times the total mass enclosed by the surface. (See **flux.**)

GAUSS METHOD FOR QUADRATURES. The integral to be evaluated

$$y = \int_a^b f(x)dx$$

is replaced by

$$\int_a^b \phi(x)dx = A_0y_0 + A_1y_1 + \cdots + A_ny_n,$$

as in the **Newton-Cotes method,** and the difference between the two integrals is minimized by fixing the values of $2(n + 1)$ quantities: $(n + 1)$ values each of the coefficients A_k and the dependent variable y_k. The latter do not result from equally spaced intervals in x, the independent variable, as is the case for most **quadrature** formulas. The $2(n + 1)$ parameters are determined by solution of simultaneous equations, which in turn depend on the real roots of the **Legendre polynomials.** Nu-

merical tables for these parameters are available.

GAUSS PRINCIPLE OF "LEAST CONSTRAINT." (1) The motion of connected points is such that, for the elementary motion actually taken, the sum of the products of the mass of each particle into the square of the distance of its deviation from the position it would have reached if free, is a minimum.

(2) The motion of a system of material points interconnected in any way and submitted to any influences, agrees at each instant as closely as possible with the motion the points would have if they were free. The actual motion takes place so that the constraints on the system are the least possible. For the measurement of the constraint, during any infinitesimal element of time, take the sum of the products of the mass of each point by the square of its deviation from the position the point would have occupied at the end of the element of time, if it had been free.

GAUSS THEOREM. A relation between a **volume integral** and a **surface integral,** which in Cartesian coordinates is

$$\int_\tau \left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z}\right) dxdydz = \int_S (\lambda u + \mu v + \nu w) dS.$$

The quantities u,v,w are functions of x,y,z having continuous first derivatives within a volume τ and they approach their values on the bounding surface continuously. The outward normal to the surface has direction cosines λ,μ,ν.

A vector form, known as the **divergence theorem,** is

$$\int_\tau \nabla \cdot \mathbf{V} d\tau = \int_S \mathbf{V} \cdot d\mathbf{S}$$

where the vector $\mathbf{V}$ has components u,v,w. However, the first form of the theorem holds even when u,v,w are not components of a vector.

A physical interpretation of the vector equation may be made, for if $\mathbf{V}$ represents the flux density of an incompressible fluid, $\nabla \cdot \mathbf{V}$ is the amount of fluid which flows from a volume $d\tau$ per second. The volume integral is thus the total loss of fluid, which must equal the rate of flow across all boundaries of the volume, and that equals the surface integral.

This theorem is also called **Green's lemma** or **theorem.**

GAUSS THEORY. See **first order theory (2).**

GAUSSIAN CURVATURE OF SPACE-TIME. See **curvature (Gaussian) of space-time.**

GAUSSIAN IMAGE POINT. For a system with **spherical aberration,** the **image point** to which the paraxial rays converge.

GAUSSIAN LENS FORMULA. (1/object distance) + (1/image distance) = (1/focal length) This is one of the most simple **first-order** relations of optics.

GAUSSIAN WAVE GROUP. A **wave group** for which

$$q(\kappa) = ae^{-\alpha(\kappa-\kappa_0)^2}.$$

Here κ is the "wavelength constant" but actually the independent variable, while α and κ_0 are arbitrary constants.

GAUSSIAN WELL. See **potential, nuclear.**

GCA. Abbreviation for ground-controlled approach.

GCI. Abbreviation for ground- (or ship-) controlled interception.

GEE. A navigational system similar to **loran.**

GEGENBAUER FUNCTION. A solution of the **differential equation**

$$(z^2 - 1)u'' + (2n + 1)zu' - a(a + 2n)u = 0.$$

For integral values of a, the solution becomes the Gegenbauer polynomial. This function is a special case of the **Gauss hypergeometric function.**

GEIGER COUNTER. See **counter, Geiger.**

GEIGER FORMULA. A relationship between the initial velocity of **α-particles** and their range. This relationship, which was derived from measurements on radium C and was later found to apply to α-particles from various sources, which have ranges from 3 to 7 cm, is of the form

$$V_0^3 = aR$$

where V_0 is the initial velocity of the α-particles at the source; a is a constant having the same value for α-particles from various sources, namely 1.03×10^{27}, provided V_0 is given in centimeters per second; and R, the usual range of the α-particles, is given in the number of centimeters of air at 15°C and a pressure of one atmosphere, which the α-particles traverse from their source to a point at which they no longer produce appreciable ionization.

GEIGER-NUTALL RELATION. An empirical relationship between the **α-particle** range and **disintegration constant** of natural α-emitting radionuclides of the form:

$$\log R = A + B \log \lambda,$$

where R is the α-particle range, λ is the **disintegration constant,** A is a parameter having different values for the three natural radioactive series, and B is constant. This relationship was more closely applicable to the members of the natural series than it is to the more recently discovered α-emitters, especially those produced artificially. Current theory does not substantiate the relationship except for the general trend.

GEIGER REGION OF A RADIATION COUNTER TUBE. (See **plateau characteristic.**) The range of applied voltage in which the charge collected per isolated count is substantially independent of the nature of the **initial ionizing event.**

GEIGER THRESHOLD OF A RADIATION COUNTER TUBE. The lowest applied voltage at which the charge collected per isolated tube count is substantially independent of the nature of the **initial ionizing event.**

GEISSLER TUBE. Geissler manufactured a variety of gas discharge tubes at moderate exhaustion, which exhibited bright glow discharges and sometimes marked **fluorescence** effects. A form very useful in **spectroscopy** consists of two elongated bulbs, one containing the **cathode** and one the **anode,** and connected by a straight capillary section. The glow is most intense in the capillary, which is by its shape especially adapted to be placed in front of a spectroscope slit Such tubes may be conveniently operated by an induction coil or a small transformer; though the latter is likely to overheat them and may even fuse the electrodes, unless a protective series resistor is employed.

GEL. A two-component colloidal system of a semi-solid nature, rich in liquid. The gelling component is usually of the lyophilic type and present in concentrations less than about 10 per cent. The gel, or semi-solid form of a colloidal system, is related to the **sol,** or liquid form, in that they are usually mutually transformable.

GEL(S), ELASTIC AND NON-ELASTIC. Gels are sometimes classified according to their behavior when the dispersing medium is removed. Elastic gels such as gelatin and agar retain their elasticity, remain coherent and do not become amorphous when desolvated. Non-elastic gels, such as gels of chromic oxide and silica, lose their elasticity and appear amorphous on drying.

GELLING POINT. The temperature at which various **colloidal solutions,** or other semi-liquids, become solid. It is a function of the concentration as well as of the temperature of the substance or substances.

GENERAL CIRCULATION. The grand wind system of the entire earth, also called atmospheric circulation.

GENERAL RELATIVITY THEORY. See **relativity theory, general.**

GENERALIZED COORDINATES AND MOMENTA. See **coordinates and momenta, generalized.**

GENERALIZED MOMENTA. See **coordinates and momenta, generalized.**

GENERALIZED VELOCITIES. In particle mechanics, the time rates of change of the **generalized coordinates.**

GENERATING FUNCTION. A method of representing a function in terms of another function containing one or more variables. These **generating functions** give the function to be generated as coefficients involving the new variable parametrically. Some examples follow:

1. Legendre polynomials

$$(1 - 2xy + y^2)^{-1/2} = \sum_{n=0}^{\infty} P_n(x) y^n$$

2. Associated Legendre polynomials

$$\frac{(2m)!(1-x^2)^{m/2}y^m}{2^m m!(1-2xy+y^2)^{m+\frac{1}{2}}} = \sum_{n=m}^{\infty} P_n{}^m(x)y^n$$

3. Bessel functions of integral order

$$\exp\left[\frac{z}{2}\left(u-\frac{1}{u}\right)\right] = \sum_{n=0}^{\infty} J_n(x)u^n$$

4. Hermite polynomials

$$\exp[x^2-(z-x)^2] = \sum_{n=0}^{\infty} \frac{H_n(x)z^n}{n!}$$

5. Laguerre polynomials

$$(1-z)^{-1}\exp\left(\frac{-xz}{1-z}\right) = \sum_{n=0}^{\infty} \frac{L_n(x)z^n}{n!}$$

6. Associated Laguerre polynomials

$$(-1)^k(1-z)^{-1}\left(\frac{z}{1-z}\right)^k \exp\left(\frac{-xz}{1-z}\right) = \sum_{n=k}^{\infty} \frac{L_n{}^k(x)z^n}{n!}$$

7. Tschebyscheff polynomials

$$\frac{1-xy}{1-2xy+y^2} = \sum_{n=0}^{\infty} T_n(x)y^n$$

GENERATION RATE (IN A SEMICONDUCTOR). The time rate of creation of **electron-hole pairs.**

GENERATION TIME. The average time between successive generations of thermal fissions, in a **nuclear reactor.** It is equal to the sum of the slowing down time of the fast fission neutrons and the diffusion time (lifetime) of the thermal neutrons. (See **neutrons, fast** and **neutrons, thermal.**)

GENERATOR, ACOUSTIC. A **transducer** which converts electric, mechanical, or other forms of energy into sound.

GENERATOR, ALTERNATING - CURRENT. See **alternator.**

GENERATOR, DIRECT - CURRENT. See **direct-current generator.**

GENERATOR, DOUBLE-CURRENT. See **double-current generator.**

GENERATOR (ELECTRICAL). Electric generators are built in all capacities, to suit the smallest and the largest installations. They can produce **alternating current** or **direct current** (see **alternator** and **direct-current generator**) depending on the design, but the origin of the electrical energy is the same, whether the final product be a-c or d-c. To understand the action of the generator, examine Fig. 1, which represents a soft **iron core** rotating between the poles of a permanent magnet, and having the slots on the surface, in which is embedded a coil of wire. It is apparent that as the coil rotates, carried by the soft-iron armature, it will cut across the **flux** lines extending from pole to pole. When this apparatus is connected to stationary leads through the medium of slip rings, and brushes resting thereon, it becomes an elementary **alternator.** If, instead of slip rings, a split segment, such as that shown in Fig. 2, is connected to the ends of the coil, the reverse of the current in the coil will occur when alternate segments of the slip ring (an elementary commutator) are opposite one of the **brushes.**

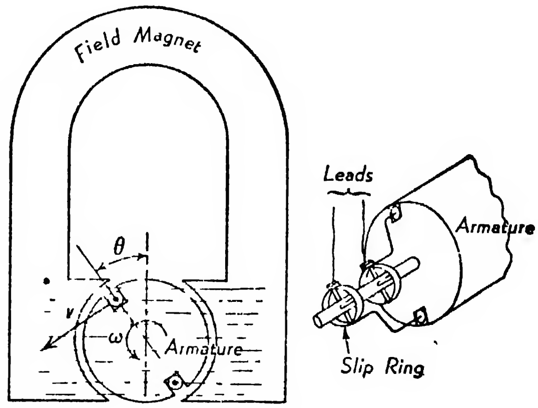


Fig 1

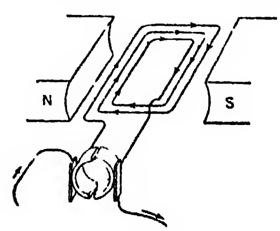


Fig 2

This gives unidirectional current in the exterior leads, although it would be quite variable with only one coil in the **armature.** A uniform and unidirectional current is the result of many single-coil armatures so connected that the resultant current is the sum

of several individual outputs. With sufficient overlap, the resulting current will be uniform and unidirectional. When the coil is revolving with an angular velocity ω, at the position indicated, the speed of cutting vertically across flux lines is $v \cos \omega t$. The time is measured from the vertical position of the coil, and angle θ is ωt When a wire cuts a magnetic field having a flux density represented by B and has a length and velocity represented by l and v, the voltage generated is $Blv/10^8$ volts, thus the voltage generated any instant t, t being measured from the point of minimum generated voltage, is $Blv/10^8 \sin \omega t$.

The **d-c generator** is an ordinary dynamo machine having a multiple-coil winding, the ends of the coils of which are connected to a multiple-segment commutator. The armature is usually rotating, and the field stationary.

GENERATOR, INDUCTOR (ALTERNATOR). A rotating machine which may be used to generate large amounts of power at frequencies as high as hundreds of kilocycles The machine operates on the principle of variable **reluctance.** An appropriately-shaped rotor changes the air-gap reluctance, and thus the flux, at a cyclic rate The alternating flux is made to link a coil, thus producing the desired induced voltage. These devices were the power sources for some of the first long-range, radio-telephone communication systems, and many of the original machines are still in use. They are also employed in industry to supply power to induction-heating systems.

GENERATRIX. Also called generator. (See **conical surface; ruled surface.**)

GEODESIC. That curve connecting two fixed points which has an extreme length (maximal or minimal). In three-dimensional Euclidean geometry, the geodesic is clearly a straight line; if the path is constrained to the two-dimensional surface of a sphere, it is a segment of a great circle In the non-Euclidean geometries appropriate to the general relativity theory, the geodesic is the path followed by a particle upon which no electromagnetic forces act. (See **relativity theory, general**).

GEOMETRIC CAPACITANCE. See **capacitance, geometric.**

GEOMETRIC DISTORTION. Any aberration which causes the reproduced picture to be geometrically dissimilar to the perspective plane-projection of the original scene.

GEOMETRIC MEAN. The nth **root** of the product of n positive quantities x_i

$$G = (x_1 x_2 x_3 \cdots x_n)^{1/n}.$$

GEOMETRIC PROGRESSION. A **sequence** of the form $a, ar, ar^2, ar^3, \cdots$. The last term, $l = ar^{n-1}$. (See **series, geometric.**)

GEOMETRICAL OPTICS. This branch of physics treats light as if it were actually composed of "rays" diverging in various directions from the source and abruptly bent by **refraction** or turned back by **reflection** into paths determined by well-known laws. The idea that light travels in straight lines is here uppermost, while its wave character and other physical aspects are lost sight of Thus the image of a point A, if "real," is simply another point B through which the rays diverging from A ultimately pass after the several reflections or refractions produced by the mirrors, lenses, etc , of the optical system If the image B is "virtual," the rays appear to be diverging from it, but only because their direction has been so changed that if produced backward, the lines along which they now travel would intersect at B A real image of a lamp may easily be formed by a reading glass; a virtual image, by a plane mirror. (See **optical instruments, eyepieces, spherical aberration,** etc.)

GEOMETRICAL SIMILARITY OF FLUID FLOW. Two fluid flows are geometrically similar if the boundary conditions of one may be transformed into the boundary conditions of the other by a simple change in the scales of length and velocity, i.e., one flow is a model of the other

GEOMETRY. (1) Study of the properties, measurement, and relations between lines, angles, surfaces, and solids. In Euclidean geometry, the axioms and postulates of Euclid are used. Plane geometry is concerned mostly with angles, triangles, polygons, circles, and other figures which can be drawn with ruler and compass; solid geometry involves figures in three dimensions, such as planes, spheres, cubes, polyhedrons. **Non-Euclidean geometry** discards one or more of the Euclidean postulates. Other specialized geometries are ana-

lytic, descriptive, differential, projective, synthetic.

(2) The physical relationship and symmetry of the portions of an assembly. In neutron calculations, plane, cylindrical, and spherical geometries are arrangements having the corresponding symmetries. In cross-section measurements, good geometry refers to the case where very few detected neutrons have suffered a collision in the target. In poor geometry almost all particles leaving the target are detected. In general, good geometry refers to the case where the source subtends small angles at the detector, and poor geometry refers to the case where the source and detector are close together, subtending a large angle The terms "good" and "poor" do not necessarily carry their usual connotations; in certain experiments poor geometry may be preferable to good geometry. (See **good geometry.**)

GEOMETRY, ANALYTIC. Study of geometry by algebraic methods In two dimensions, considerable attention is given to **conic sections**; in three dimensions, to **quadric surfaces.** Also called coordinate geometry.

GEOMETRY, DESCRIPTIVE. Graphical description of objects in three dimensions; the mathematical technique of mechanical or technical drawing.

GEOMETRY, DIFFERENTIAL. Application of **differential calculus** to the study of curves and **surfaces.** Methods of **tensor calculus** are frequently used.

GEOMETRY FACTOR (RADIATION). The average solid angle at the source subtended by the aperture or sensitive volume of the detector, divided by the complete solid angle ($4\pi r$). Frequently used loosely to denote counting yield or **counter efficiency.**

GEOMETRY, NON-EUCLIDEAN. Geometry in which not all the axioms and postulates of Euclid are assumed. In particular, the classical non-Euclidean geometries are obtained by replacing the parallel postulate of Euclidean geometry by other assumptions.

In hyperbolic geometry, usually credited to Lobachevsky, all of Euclid's axioms are adopted with the exception of the parallel postulate, which is replaced by the assumption that through any point there are two or more lines which do not intersect a given line in the plane. Many theorems are the same as in Euclidean geometry, but many are different; for example, the sum of the three angles of a triangle is less than two right angles.

In elliptic geometry, the parallel postulate of Euclid is replaced by the assumption that through a given point all lines intersect a given line in the plane.

GEOMETRY, PROJECTIVE. Study of geometric figures projected on a plane. (See also **geometry, synthetic.**)

GEOMETRY, RADIATION. Refers to a description of the dimensions and relative spatial positions of the source, detector, and any object or materials which can absorb, scatter, or alter the radiation being measured. Loosely, **geometry factor.**

GEOMETRY, SYNTHETIC. Application of synthetic or deductive methods to the study of geometry The term is often used as synonymous with pure geometry

GEON. Entity consisting of an electromagnetic field held together by the gravitational attraction arising from the energy, and hence mass, of the field. Not observed, but the possibility of its existence is a consequence of classical electromagnetic and gravitational theories.

GEOSTROPHIC WIND. The wind that is the result of a balanced pressure **gradient** and **Coriolis force.** Geostrophic winds blow in straight or nearly straight lines. Low pressure is to the left of the wind direction in the northern hemisphere when the observer stands with back to the wind.

GERMANIUM. Metallic element. Symbol Ge. Atomic number 32.

GETTER. A metallic deposit in a vacuum tube whose function is to absorb residual gas. The best getters are the electropositive metals such as sodium, potassium, magnesium, calcium, strontium, and barium.

GETTER FILM, DISTILLATION METHOD OF FORMING. A method of depositing a film of sodium or potassium in a vacuum vessel in which successive distillations are performed within, and finally from, a side tube provided with a series of sealed-off constrictions.

GETTER FILM, ELECTROLYTIC METHOD OF FORMING. A method of forming a deposit of sodium, available where the vacuum vessel is of lime-soda glass. It is well known that sodium may be electrolyzed through lime-soda glass. If, therefore, a thermionic source of electrons is provided inside an evacuated sealed-off vessel, part of which is dipped into a suitable liquid kept at a high potential relative to the source of electrons, a current will pass, carried by electrons between the thermionic cathode and the inner surface of the glass, and by ions within the glass. The only ions in the glass that are mobile are sodium ions, and thus pure sodium is released at the inner surface of the envelope.

GETTERING, "CONTACT." The absorption of gas resulting from its contact with the already dispersed **getter** film.

GETTERING, DISPERSAL. The absorption of gas during the dispersal of the **getter** through the vacuum tube.

GETTERING, ELECTRIC-DISCHARGE. Absorption of gas may be greatly accelerated by passing an ionizing electron discharge through the gas. The gas is ionized, and the ions are neutralized when they impinge on an electrode, so that the final product is neutral gas atoms. These are then easily absorbed by the **getter.**

GHOST(S). (1) In spectroscopy, false images of a spectral line produced by irregularities in the ruling of diffraction **gratings.** Rowland ghosts are false images grouped symmetrically on both sides of the true line. Lyman ghosts are false orders of spectra for which the **order** is not an integer. (2) In television, the spurious image (see **ghost image**) resulting from an **echo.**

GHOST IMAGE. In television, a second image appearing on the receiver screen, superimposed on the desired signal. These images are caused by reflected rays arriving at the receiving antenna some small interval after the desired wave. A single, reflected ray from a stationary object will produce a single, clear ghost, while a number of reflected rays arriving at assorted times creates an effect known as "smearing" or "smear ghost." Ghosts may also be produced wi[illegible] intensity reversal (white becomes black and vice-versa) due to a suitable phase of the secondary signal with respect to the primary signal, occurring on a suitable amplitude range of the received primary signal. This ghost is customarily called a negative ghost.

GIANT AIR SHOWER. The same as extensive shower. (See **shower, extensive.**)

GIAUQUE-DEBYE METHOD. See **adiabatic demagnetization, cooling by.**

GIBBS ADSORPTION EQUATION. An equation relating **adsorption** and **surface tension,** derived by thermodynamics. For a two-component system involving a solvent (1) and solute (2), the surface excess Γ_2 is given by

$$\Gamma_2 = -\frac{1}{RT}\frac{d\gamma}{d\ln(f_2N_2)}$$

where f_2 is the activity coefficient of component 2, N_2 is the mole fraction of component 2, γ is the surface tension of the solution

For ideal solution (see **solution, ideal**) $f_2 = 1$, and in dilute solutions the concentration c_2 is proportional to the mole fraction N_2.

$$\Gamma_2 = -\frac{1}{RT}\frac{d\gamma}{d\ln c_2}.$$

From this equation it is apparent that when the **surface tension** decreases with solute concentration, the surface excess is a positive quantity. Conversely the surface excess is a negative quantity for those substances which increase the surface tension (The surface excess is the surface concentration of solute (component 2 in above equations) per unit area of interface.)

GIBBS-DUHEM EQUATION. In a system of two or more **components** at constant temperature and pressure, the sum of the changes for the various components, of any **partial molar quantity,** each multiplied by the number of moles of the component present, is zero. The special case of two components is the basis of the Gibbs-Duhem equation of the form:

$$n_1d\bar{X}_1 = -n_2d\bar{X}_2$$

in which n_1 and n_2 are the number of moles of the respective components and $\bar{X}_1$ and $\bar{X}_2$ are the partial molar values of any extensive property of the components.

GIBBS FREE ENERGY. Defined under **free energy (1).**

GIBBS FUNCTION. Defined under **free energy (1).**

GIBBS-HELMHOLTZ EQUATION. A thermodynamic relationship useful in calculating changes in the energy or enthalpy (**heat content**) of a system, from certain other data. Two useful general forms of this equation are:

$$\Delta A - \Delta U = T\left(\frac{\partial(\Delta A)}{\partial T}\right)_V$$

$$\Delta G - \Delta H = T\left(\frac{\partial(\Delta G)}{\partial T}\right)_P$$

in which A is the work function, defined in this book under **free energy (2)**, U is the **internal energy** of the system, T is the absolute temperature, V is the volume, P is the pressure, G is the Gibbs free energy (see **free energy (1)**), and H is the heat content of the system.

GIBBS-HELMHOLTZ EQUATION FOR A REVERSIBLE CELL. If the heat of the chemical reaction taking place in the cell is ΔH, F is the **Faraday constant** and the reaction takes place by the migration of an ion bearing a charge j, then

$$\Delta H = jF\left(\mathcal{E} - T\frac{d\mathcal{E}}{dT}\right),$$

where $\mathcal{E}$ is the e.m.f. of the cell.

GILL-MORREL OSCILLATOR. A form of **Barkhausen oscillator.**

GIBBS PHENOMENON. Unusual behavior shown by a function with a **discontinuity,** when it is approximated by a finite number of terms in a **Fourier series.** As a simple example, consider $f(x) = 1, 0 < x < \pi$; $f(x) = -1, \pi < x < 2\pi$. The sum of the first n terms in the Fourier series converges to ± 1 as $n \rightarrow \infty$, except at the discontinuities, where it converges to zero. However, the maximum value of the first n terms approaches 1.179. A Fourier expansion for a function with a discontinuity should be examined carefully for this phenomenon.

GILBERT. The unit of **magnetomotive force** in the **emu system.** One gilbert = $10/4\pi$ **ampere turns.**

GIMMICK. The colloquial name given to a small **capacitor** (1–5 micromicrofarads) formed from two insulated wires twisted together.

GLADSTONE-DALE LAW. When a substance is compressed, or its temperature varied, the density alters and there is a corresponding variation in the **refractive index.** The form of this relationship is:

$$\frac{n - 1}{\rho} = k$$

where n is the index of refraction, ρ is the density, and k is a constant. (See, however, **Lorentz-Lorenz relation.**)

GLAN PRISM (GLAN-THOMPSON PRISM). See **prism, Glan.**

GLAN SPECTROPHOTOMETER. An instrument similar to an ordinary **spectrometer,** but with certain modifications making possible the comparison of two sources.

GLANCING ANGLE. (1) The angle between a ray and the tangent plane to a surface. The complement of the **angle of incidence.** (2) The term is often used as a modifier, to indicate the incidence of a beam at a very small angle with the surface.

GLASS. See **vitreous state.**

GLASS ELECTRODE. See **electrode, glass.**

GLIDE PLANE. (1) A **symmetry element** of a **space lattice,** such that the lattice remains unchanged after a **reflection** in the plane, followed by a **translation** parallel to the same plane. (2) Same as **slip plane** in theory of **dislocations.**

GLIMMSCHICHT METHOD. See discussion of **cathode glow.**

GLOBAR (GLOBAR LAMP). A ceramic rod consisting largely of silicon carbide (Carborundum) which has some electrical conductivity at room temperature and which can be heated to an almost white heat in air without rapid deterioration. It radiates almost like a **black body.** Globars are commonly used as a radiation source like **Nernst** glowers in infrared spectrometers. They have the advantage over Nernst glowers of not requiring a secondary heat source for starting and in being more rugged; however they cannot be

made as small as Nernst glowers and, in general, some sort of cooling device, such as a water jacket, is necessary.

GLORY. A series of concentric colored rings around the shadow of the observer, or of his head only, cast upon a cloud or fog bank.

GLOSSIMETER. An instrument for measuring the ratio of the light regularly or specularly reflected from a surface, to the total light reflected.

GLOW, ABNORMAL. See **abnormal glow.**

GLOW DISCHARGE. A discharge of electricity in a low-pressure gas, characterized by its low **current-density,** and a space potential in the vicinity of the cathode that is considerably higher than the **ionization potential** of the gas, but less than the **sparking potential.** The spectrum of the emitted light has a number of luminous bands of different widths and intensities.

GLOW DISCHARGE TUBE. See **tube, regulator.**

GLOW - DISCHARGE, COLD - CATHODE TUBE. See **tube, glow-discharge cold-cathode.**

GLOW POTENTIAL. The potential across a glow discharge which is less than the sparking potential, but greater than the **ionization potential** of the gas. This potential is quite constant as a function of the current in the **normal glow** region, where the cathode is not completely covered with glow. As the cathode becomes covered with glow, an increase in current causes an increase in voltage, and the glow is now abnormal. Sufficient excursion into the abnormal glow region will cause an abrupt drop in potential, and the discharge will be an arc.

GLUE LINE HEATING. In **dielectric heating** usage, an arrangement of electrodes designed to give preferential heating to a thin film of material of relatively high loss factor between alternate layers of relatively low loss factor.

G_m. See **transconductance.**

GO, NO-GO DETECTOR. An instrument which has only two stable states of indication, and which therefore will give full response to any stimulus capable of actuating it. For example, a common fuse is a go, no-go detector, since either it is intact, or it is burned out. An ammeter, however, can respond continuously to the same current.

GOBO. (1) A **flag** used to shield the lens of a television camera from the direct rays of light. (2) A **sound shield** placed around a microphone to reduce unwanted sounds.

GOLAY PNEUMATIC CELL. A small transparent cell containing gas which is used to detect radiation. A very thin film within the cell absorbs incident radiation, which increases the cell temperature and pressure. Changes in pressure are recorded as indications of the amount of incident radiation.

GOLD. Metallic element. Symbol Au Atomic number 79.

GOLD NUMBER. When certain **colloids** (hydrophilic), such as gelatine, are added to a gold sol, the gold sol is strongly protected against the flocculating action of electrolytes This protective action on red gold sols may be measured by utilizing the color change red to blue which indicates the first stage of coagulation. The "gold number" as defined by Zsigmondy is the weight in milligrams of protective colloid which is just sufficient to prevent the change from red to blue in 10 cm^3 of a standard gold sol (0.0053 to 0.0058 per cent Au) after the addition of 1 cm^3 of a 10 per cent sodium chloride solution.

GOLDSCHMIDT LAW. The structure of a crystal is determined by the ratio of the numbers, the ratio of the sizes, and the properties of polarization of its structural units, i.e., atoms or ions.

GONIOMETER. (1) An instrument for measuring the angles between the reflecting surfaces of a crystal or a prism. (2) A radio receiver and **directional antenna** system for determining the angle of arrival of transmitted waves.

GOOD GEOMETRY. In nuclear physics measurements, an arrangement of source and detecting equipment such that the use of finite source size and finite detector aperture introduces little error. For example, consider the measurement of the reaction energy Q, in the reaction $A + B \rightarrow C + D + Q$. Here particles B are supposed to strike target nuclei A, releasing the disintegration particles

D and producing the recoil nuclei C. The measurement of Q depends upon the measurement of the energy of the particles D, and this in turn is dependent on the angle of emission of D relative to the direction of incident particles B. The necessarily finite sizes of the target and the detector aperture introduce an uncertainty in this angle. "Good geometry" is said to prevail when the resultant uncertainty in the measurement of Q is not much larger than the errors introduced by other factors such as the target thickness and the energy inhomogeneity of the incident particles.

GOUDSMIT AND UHLENBECK ASSUMPTION. The assumption of electron spin, which was advanced to explain the **multiplicity** of many spectra, which is due to the contribution which the spin makes to the total angular momentum, and which is quantized in the **spin quantum number.**

GOUDSMIT Γ-SUM RULE. For a given electron configuration, the sum of the Γ values corresponding to a given value of the magnetic quantum number M is independent of the field strength H. (For discussion of Γ, see **Landé Γ-permanence rule.**)

GRADIENT. (1) A **vector** obtained by the application of the vector **differential operator** ∇ to a scalar point function. In rectangular coordinates it is

$$\mathbf{grad}\,\phi = \nabla\phi = \mathbf{i}\frac{\partial\phi}{\partial x} + \mathbf{j}\frac{\partial\phi}{\partial y} + \mathbf{k}\frac{\partial\phi}{\partial z}$$

where **i, j, k** are **unit vectors.** It expresses, both in magnitude and direction, the greatest space rate of change of the scalar ϕ. At any point P, it is normal to the surface $\phi(x,y,z) =$ constant, which passes through P. (2) The increase or decrease of a meteorological element with respect to distance, either horizontal or vertical, e.g., a barometric gradient of plus 10 millibars per 1000 miles, or a vertical temperature gradient of minus 4°C per 1000 feet altitude, the latter being more commonly called the **lapse rate.**

GRADIENT COUPLING. Type of postulated coupling between nucleons and other particles (**mesons, β-particles** and **neutrinos**) in which the interaction energy depends explicitly on the first order derivatives of the wave functions with respect to position and time.

GRADIENT WIND. The wind which blows when the **pressure gradient, Coriolis force,** and centrifugal force are balanced, and when there is no acceleration. In clockwise systems in the northern hemisphere Coriolis force balances both centrifugal force and the pressure gradient; in the counterclockwise system, the pressure gradient balances both centrifugal force and Coriolis force.

GRADIOMETER. A **flux-gate magnetometer** arranged to give an output proportional to the gradient of a magnetic field.

GRAEFFE METHOD. A procedure for obtaining approximate values of the **roots** of a **polynomial.** Known also by the names of Dandelin and Lobachevsky, its advantages over other methods are that no first order approximation to the root is needed and that all roots, both real and complex, are obtained in one operation.

The given polynomial, conveniently written in the form $x^n + a_1x^{n-1} + \cdots + a_n = 0$, is repeatedly squared and the coefficients of equal powers of x are collected. After this has been done s times, the coefficients are the numbers $1, m_1, m_2, \cdots, m_n$. If $r_1, r_2, \cdots, r_n$ are the real roots of the polynomial, their absolute magnitudes are $|r_1|^p = m_1$; $|r_2|^p = m_2/m_1$; $\cdots$; $|r_n|^p = m_n/m_{n-1}$, where $p = 2^s$. The signs of the roots must be found in some other way. Appropriate modification of the method also furnishes the complex roots, which occur in pairs.

GRAHAM LAW. The rate of **diffusion** of a gas is inversely proportional to the square root of its density.

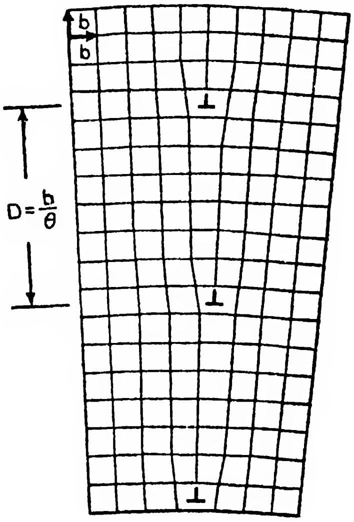
GRAIN. (1) A small particle. (2) A unit of mass in the **English system** equal to the 480th part of an apothecaries' ounce, or equal to the 5760th part of an apothecaries' pound. The conversion factors of grains to avoirdupois units, and to metric units, are as follows:

$$\begin{aligned} 437.5 \text{ grains} &= 1 \text{ avoirdupois ounce} \\ 15.4324 \text{ grains} &= 1 \text{ gram} \\ 1 \text{ grain} &= 0.0648 \text{ gram.} \end{aligned}$$

See also **grain boundary** and **grain, photographic.**

GRAIN BOUNDARY. The surface separating two regions of a solid in which the **crystal axes** are differently oriented. It has been shown that such a boundary may be thought

of as built up of an array, or network of **dislocations,** whose spacing D depends on the



A simple grain boundary. The plane of the figure is parallel to the cube face and normal to the axis of relative rotation of the two grains, which have a common cube axis and an angular difference in rotation θ (By permission from "Dislocations in Crystals" by Read, Copyright 1953, McGraw-Hill Book Co.)

tilt θ of the axes across the surface. The energy (per unit area) of a grain boundary is given by

$$E/E_m = (\theta/\theta_m)\{1 - \ln(\theta/\theta_m)\}$$

where E_m and θ_m are parameters depending on the material.

GRAIN BOUNDARY RELAXATION. A source of **internal friction** in solids due to the motion of **grain boundaries** under stress.

GRAIN, PHOTOGRAPHIC. A small particle of metallic silver remaining in a photographic emulsion after development and fixing. In the agglomerate, these grains form the dark area of a **photographic image.**

GRAININESS, PHOTOGRAPHIC. The visible coarseness of a photographic material, under specified conditions, due to silver grains in a developed photographic film.

GRAM. (1) A unit of mass, abbreviation gm or gr. One one-thousandth of a kilogram. (2) A unit of force, abbreviation gf or gr. The weight of a gram mass at the earth's surface. If greater precision is needed, it is specified that this weight should be measured at a point where the acceleration due to gravity is 980.665 cm/sec^2.

GRAM-ATOM. That quantity of an element having a mass in grams numerically equal to the **atomic weight.** One gram atom contains the **Avogadro number** of atoms.

GRAM-ATOMIC WEIGHT. The weight of a **gram-atom.**

GRAM DETERMINANT. Used in testing functions for linear dependence or independence. Let vectors $\mathbf{u}_1, \mathbf{u}_2, \cdots, \mathbf{u}_n$ be given in an n-dimensional space. Then the **Gram determinant** has as elements $\mathbf{u}_i \cdot \mathbf{u}_j$, the **scalar product,** or the **Hermitian scalar product** if the **vector space** is complex. If the determinant vanishes, this is a necessary and sufficient condition that the vectors are linearly dependent; if the determinant does not vanish, the vectors are independent. A similar procedure may be used for n functions $\phi_1, \phi_2, \cdots, \phi_n$ and the elements of the determinant become $\int \phi_i \phi_j^* dt$. (See also **Wronskian.**)

GRAM-EQUIVALENT. The **gram-atomic weight** of an element (or formula weight of a radical) divided by its **valence.** In the case of multivalent substances there will be more than one value for the gram-equivalent, viz., Fe^{++} = 27.92 gm, Fe^{+++} = 18.61 gm, and the proper value for the particular reaction must be chosen.

GRAM-MOLECULAR VOLUME. The volume occupied by 1 **mole** of an element at 0°C and 760 mm pressure. For an ideal gaseous element it is 22 242 liters.

GRAM-MOLECULAR WEIGHT. That amount of a pure substance having a weight in grams numerically equal to the **molecular weight.** One gram-molecular weight contains the **Avogadro number** of molecules. It is also designated as the mole or mol.

GRAM-RAD. A unit of integral absorbed dose, recommended by the International Commission on Radiological Units (July, 1953). It is 100 ergs.

GRAPH. A line drawing expressing a relation between two variables; or more generally, any record produced by physical methods.

GRAPHICAL DIFFERENTIATION. Estimation of the derivative of a curve by measuring the **slope** of a tangent to the graph of the curve.

GRAPHICAL INTEGRATION. Obtaining the value of an integral by measuring the area under the graph of the function, by counting the squares, or by cutting out and weighing the graph. (See also **planimeter, polar.**)

GRAPHICAL STATICS. The **equilibrium of forces** is often treated graphically in such practical problems as the stresses in the members of a framed structure If three concurrent forces are in equilibrium, the three vectors drawn to a common scale to represent them may be made to form a closed triangle (Fig 1); or if more than three, a closed polygon (Fig. 2). The principle may be extended and is much used in the calculation of the forces in a truss by means of the so-called stress diagram. A simple example is shown in Fig. 3, which represents a small roof-truss with equal loads resting on it at the joints A, B, C, D, E, and supported by the upward reactions of the walls at A and E. The several compartments of the figure are numbered, and both the external forces and the forces acting along the members between these compartments are represented, both in magnitude and direction, by the lines joining the corresponding numbers in the stress diagram. For example, the compressive force in the strut BF is represented by the line 8–9, while the tension in the vertical rod CF is given by 9–10. The closed figure 5–4–10–9–5 in the stress diagram indicates the equilibrium of the forces acting at the joint C. This method of analysis is attributed to Maxwell.

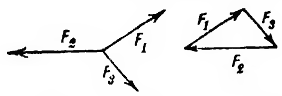


Fig 1 Three forces in equilibrium

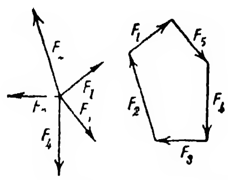


Fig 2. Five forces in equilibrium

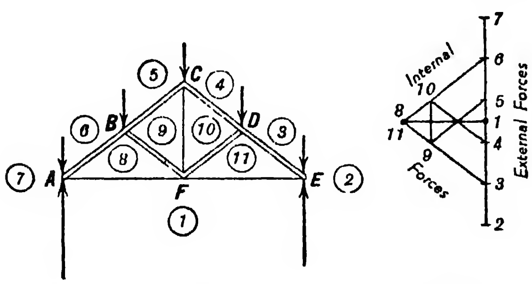


Fig 3 Elevation of truss with corresponding stress diagram

In the graphical solution of some types of **trusses** it is found on reaching a particular joint that the arrangement of members is such that there are more than two unknowns. It is then necessary to replace the unknowns by a substitute system which reduces the number of unknowns at the joint to two. The substitute system consists of a single member inserted in such a way that the truss remains stable and determinate This member is called a substitute, fictitious or phantom member. When the solution reaches a joint where the stress in the members is unaffected by the substitution, the substitute arrangement is replaced by the original arrangement. The graphic procedure is reversed in direction to find the stress in the original members.

GRASHOF NUMBER. A non-dimensional parameter appearing in the theory of flows caused by free convection It is

$$G = \frac{\alpha\theta g d^3}{\nu^2}$$

where θ is the temperature difference producing the convection, α is the coefficient of thermal expansion of the fluid, d is the length scale of the system, ν is the kinematic viscosity Flows without large density changes caused by the temperature differences are dynamically similar if the Grashof and **Prandtl numbers** are equal.

GRASS. The pattern on the **cathode-ray-tube** display of a radar or similar system, which is produced by the random noise output of the receiver.

GRATICULE. A **reticle** composed of lines ruled on a transparent plate, instead of the usual fine threads or wires.

GRATING. Any frame-work or lattice-work, consisting of a regular arrangement of bars,

rods, or other long, narrow objects with interstices between them. A **diffraction** grating consists of rulings upon the surface of a light-transmitting or light-reflecting substance; it is used for the production of spectra.

GRATING, CONCAVE. See **concave grating.**

GRATING, REFLECTION. See **reflection grating.**

GRATING REFLECTOR. See **reflector, grating.**

GRATING, REPLICA. See **replica grating.**

GRATING, ULTRASONIC SPACE. See **ultrasonic space grating.**

GRAVITATION CONSTANT. See **gravitation, Newton law of universal.**

GRAVITATION, EINSTEIN LAW OF. See **Einstein law of gravitation.**

GRAVITATION, NEWTON LAW OF UNIVERSAL. Every particle of matter in the universe attracts every other particle with a force directed along the line joining the particles, directly proportional to the product of the masses and inversely proportional to the square of their distance apart. The coefficient of proportionality, called the gravitation constant and denoted by G, has a value $6.670 \times 10^{-8} \pm 0.005$ dyne cm^2/gm^2.

GRAVITATION, NORDSTROM THEORY OF. See **Nordstrom theory of gravitation.**

GRAVITATION, THEORY OF. See **relativity theory, general; Whitehead theory; Nordstrom theory; Newton theory of gravitation.**

GRAVITATION, WHITEHEAD THEORY OF. See **Whitehead theory of gravitation.**

GRAVITATIONAL FIELD. A region in which a particle is subject to a gravitational force. The magnitude of the field is the force per unit mass. (See **gravitation, Newton law of universal.**)

GRAVITATIONAL MASS. Mass of an object, regarded as the generator of a gravitational field. On the Newtonian theory, the gravitational potential due to a particle of gravitational mass m is $-Gm/r$ at a point distant r from the particle. The equality of gravitational mass and **inertial mass** is a consequence of the principle of equivalence. (See **equivalence principle.**)

GRAVITATIONAL POTENTIAL. For a point in a gravitational field (see **field, gravitational**), the amount of work which must be done on a particle of unit mass to move it from the point to infinity. It becomes equal to the **potential energy** per unit mass at the point in question if the potential energy is taken to be equal to zero at infinity, which is usually the case.

GRAVITATIONAL RADIUS. The gravitational radius of a mass m is the length Gm/c^2 (G is the **gravitational constant,** c, the **velocity of light in vacuo**). For the sun this is 1.47 km, for the earth 5 mm.

GRAVITY. See **gravitation (Newton law of universal).**

GRAVITY CELL. See **cell, gravity.**

GRAY BODY. A **radiator** whose **spectral emissivity** remains constant through the spectrum, being in a constant ratio, less than unity, to that of a **complete radiator** (black body) at the same temperature.

GRAY FILTER. See **neutral-density filter.**

GRAY SCALE. A series of achromatic tones ranging from black to white. A gray scale may be divided into three or more steps but 10 is a common number of divisions. A gray scale is sometimes included with the subject when making a color photograph so that measurements of its densities on the separation negatives or tripack will give the density range of that stage in the reproduction. A gray scale is helpful in controlling the processing stages in the analysis and synthesis of a color photograph.

GREEN FORMULA. When the **Lagrange identity** is integrated between the limits (a,b), the result is **Green's formula**

$$\int_a^b \{vL(u) - u\bar{L}(v)\}dx = [P(u,v)]_a^b.$$

If the pair of **adjoint equations** is of order n, the right-hand side of the formula is a **bilinear form** in the $2n$ quantities

$$u(a),\ u'(a),\ \cdots,\ u^{(n-1)}(a);$$

$$u(b),\ u'(b),\ \cdots,\ u^{(n-1)}(b);$$

$$v(a),\ v'(a),\ \cdots,\ v^{(n-1)}(a);$$

$$v(b),\ v'(b),\ \cdots,\ v^{(n-1)}(b).$$

GREEN FUNCTION. A symmetric **kernel** $G(x,z)$ used to convert a **Sturm-Liouville equation** and its **boundary conditions** into an **integral equation.** It is defined to have the properties: (1) it is continuous over the range $a \leq x \leq b$ and has continuous derivatives of orders up to $(n - 2)$, where n is the order of the differential equation; (2) its derivative of order $(n - 1)$ is discontinuous at a point z within the range (a,b); (3) it satisfies the differential equation everywhere except at $x = z$.

GREEN THEOREM. If F, G are scalar functions and the vector $\mathbf{V} = F\nabla G$, the **Gauss theorem** in vector form gives

$$\int_\tau \nabla F\cdot\nabla G d\tau + \int_\tau F\nabla^2 G d\tau = \int_S F\nabla G\cdot d\mathbf{S},$$

where the integrals on the left are taken over a volume τ and that on the right over the surface or surfaces enclosing the volume. On exchanging F and G and subtracting the result from this equation, the **Green theorem** results

$$\int_\tau (F\nabla^2 G - G\nabla^2 F)d\tau = \int_S (F\nabla G - G\nabla F)\cdot d\mathbf{S}.$$

These relations are also sometimes known as **Gauss' theorem** or the **divergence theorem.**

GREGORIAN TELESCOPE. A reflecting **telescope** with a concave secondary mirror which reflects the light through an opening in the primary mirror, and forms a **real image** behind the primary mirror. (See **Cassegrainian telescope.**)

GREGORY FORMULA. For numerical evaluation of an integral. It is obtained from the **Newton formula for interpolation** and may be written

$$\int_a^b f(x)dx$$
$$= h\left[\frac{y_0}{2} + y_1 + y_2 + \cdots + y_{n-1} + \frac{y_n}{2}\right]$$
$$- \frac{h}{12}(\Delta y_{n-1} - \Delta y_0)$$
$$- \frac{h}{24}(\Delta^2 y_{n-2} + \Delta^2 y_0)$$
$$- \frac{19h}{720}(\Delta^3 y_{n-3} - \Delta^3 y_0)$$
$$- \frac{3h}{160}(\Delta^4 y_{n-4} + \Delta^4 y_0) - \cdots,$$

where h is the interval between equally-spaced values of the independent variable x and the quantities $\Delta^m y_k$ are **finite differences.** Gregory's formula is equivalent to the **trapezoidal rule,** with correction terms in these differences.

GREGORY-NEWTON FORMULA FOR INTERPOLATION. See the **Newton formula for interpolation.**

GRID. An electrode having one or more openings for the passage of electrons or ions. As used in **electron tubes,** the grid acts primarily to exercise control (by a voltage impressed on it) on the passage of electrons across the tube-space, without collecting more of them than are necessary. The screen grid is an additional, open-type element inserted between the control grid and the anode to reduce the interelectrode capacitance between them. The suppressor grid is inserted between the screen and anode to reduce secondary emission. In many **gas-filled tubes,** and in the **cathode-ray tube,** the grid is a solid cap-like element with a single hole for the passage of the electrons.

GRID BASE. The region of grid voltage between that which causes plate-current cutoff and that which causes grid current flow (positive grid region).

GRID BIAS. See **bias.**

GRID BIAS, AUTOMATIC. Grid-bias voltage provided by the difference of potential across resistance(s) in the **grid** or **cathode**

circuit by grid or cathode current or both. (See **bias.**)

GRID-BIAS CELL. See **bias cell.**

GRID BIAS, DIRECT. The direct component of **grid voltage.** This is commonly called grid bias.

GRID-BIAS, SELF. See **grid bias, automatic.**

GRID CHARACTERISTIC. See **electrode characteristic.**

GRID, CONTROL. A **grid,** ordinarily placed between the cathode and an anode, for use as a **control electrode.**

GRID - CONTROLLED MERCURY - ARC RECTIFIER. See **rectifier, grid-controlled mercury-arc.**

GRID CURRENT. See **electrode current.**

GRID CURRENT, CRITICAL. In a **gas tube,** the instantaneous value of **grid current** when the anode current starts to flow.

GRID-DIP OSCILLATOR. A **vacuum-tube** oscillator used for test purposes which employs a sensitive meter to read the average value of **grid current.** When a circuit having the same resonance frequency as the frequency of the oscillator is coupled to the oscillator tank-circuit, appreciable energy is coupled into the external circuit, the amplitude of oscillation decreases, and the grid current decreases thus giving the instrument its name.

GRID-DRIVE CHARACTERISTIC. A relation, usually shown by a graph, between electrical or light output and control-electrode voltage measured from **cutoff.**

GRID DRIVING POWER. The average product of the instantaneous values of the **grid current** and of the alternating component of the grid voltage over a complete cycle. This comprises the power supplied to the biasing device and to the grid.

GRID EMISSION, SECONDARY. Electron emission from a grid, resulting directly from bombardment of its surface by electrons or other charged particles.

GRID EMISSION, THERMIONIC (PRIMARY GRID EMISSION). Current produced by electrons thermionically emitted from a **grid.**

GRID-GLOW TUBE. A cold-cathode, **glow-discharge** device with at least one "grid" or starting electrode for initiating conduction between anode and cathode.

GRID LEAK. The resistance in the grid circuit of a vacuum tube. (See **tube, vacuum.**)

GRID-LEAK DETECTOR. See **detector, balanced.**

GRID MODULATION. See **modulation, grid.**

GRID POOL TANK. A grid-controlled, mercury-pool rectifier. Examples are the **excitron** and some forms of the **ignitron.**

GRID PULSE MODULATION. See **modulation, grid pulse.**

GRID-SEPARATION CIRCUIT. In **lighthouse tube** oscillator and amplifier circuits, an arrangement whereby the input and output cavities are separated by the **grid** and the position of the resonators in contact with the grid-disk. The low-frequency, lumped-parameter equivalent of this circuit would be the grounded-grid circuit.

GRID, SPACE-CHARGE. A **grid,** usually positive, that controls the position, area, and magnitude of a potential minimum or of a **virtual cathode** in a region adjacent to the grid.

GRID, SUPPRESSOR. A **grid** that is interposed between two positive electrodes (usually the **screen-grid** and the **plate**), primarily to reduce the flow of secondary electrons from one electrode to the other.

GRID VOLTAGE. See **electrode voltage.**

GRID VOLTAGE, CRITICAL. In a **gas tube,** the instantaneous value of grid voltage (defined under **electrode voltage**) at which the anode current starts to flow.

GRIEBE AND SCHIEBE METHOD. A method for observing the piezoelectric characteristics of small crystals In this procedure a number of grains of the substance are inserted between two electrodes which are placed across the **resonant circuit** of an **oscillator.** The frequency of the oscillator is changed by changing the resonant circuit and, if a resonance of one of the piezoelectric crystals occurs near the oscillator frequency, the

frequency of the oscillator will briefly be controlled by the crystal resonance. As the resonant circuit is tuned further, the natural frequency of the oscillator becomes far enough away from the crystal resonance so that it cannot control the oscillator frequency, and a jump occurs from the crystal frequency to a different frequency controlled by the oscillator constants. This jump in frequency is accompanied by a change in the plate current, so that if a pair of headphones or a loudspeaker is attached to the **plate-circuit** of the oscillator, a click is heard.

GRIFFITHS METHOD FOR MECHANICAL EQUIVALENT OF HEAT. An electrical method in which the rise in temperature of a known mass of water is compared with a measurement of electrical energy necessary to effect this rise, which is based on determinations of electromotive force, resistance and time.

GROOVE SPEED, CONSTANT. A phonograph recording system in which the linear speed of the **groove** with respect to the **stylus** is constant regardless of the groove diameter. Employed in embossed recordings.

GROTTHUSS-DRAPER, LAW OF. Only those radiations which are absorbed by the reacting system are effective in inducing chemical change.

GROUND. An electrical conductor connected to earth, or a large conductor whose **potential** is taken as zero (e.g., the steel frame of a car). A ground may be an undesirable, inadvertent, or accidental path taken by an electrical current; or it may be the deliberate provision of **conductors** well connected to the ground by means of plates buried therein, or similar device.

GROUND-CONTROLLED APPROACH. A method of landing aircraft in poor visibility by directing the operation with the aid of a ground **radar station.**

GROUND EQUALIZER INDUCTORS. Coils of relatively low inductance, placed in the circuit connected to one or more of the grounding points of an **antenna** to distribute the current to the various points in any desired manner.

GROUND NOISE. See **noise, ground.**

GROUND-PLANE ANTENNA. See **antenna, counterpoise.**

GROUND-REFLECTED WAVE. See **wave, ground-reflected.**

GROUND STATE. The state of a quantized system, e.g., a nucleus, atom or molecule, which is that of lowest energy.

GROUND SYSTEM OF ANTENNA. See **antenna, ground system of.**

GROUND WAVE. (1) In general, a surface wave (see **wave, surface**). (2) The energy which reaches the radio receiving **antenna** from the **transmitter** by travel along the surface of the earth rather than by reflection from the **ionosphere.** The ground wave is unaffected by seasonal or diurnal variations and is consequently very reliable for communication. However, it is attenuated by absorption of the earth and gradually becomes too weak to furnish a reliable signal. This attenuation depends in a complicated way upon the frequency, the soil conductivity and dielectric constant, but increases markedly with frequency. Thus, while it is suitable for communication over several thousand miles at the lower radio frequencies, over a hundred or two in the broadcast band, it becomes almost useless at the high frequencies. See **fading** for its effect on the total received signal.

GROUNDED-CATHODE AMPLIFIER. See **amplifier, grounded-cathode.**

GROUNDED-GRID AMPLIFIER. See **amplifier, grounded-grid.**

GROUNDED-PLATE AMPLIFIER (CATHODE FOLLOWER). See **amplifier, grounded-plate (cathode follower).**

GROUP. A set of elements satisfying the following conditions: (1) There is a defined operation by which to each ordered pair of elements A and B in the group G there is associated an element C of G, denoted by $C = AB$ and called the product of A and B. (2) For this operation the **associative law** holds: $(AB)C = A(BC) = ABC$ for any three elements A, B, C of G. (3) There exists: (a) a **unit element** E in G such that $EA = A$ for every element A of G, and (b) to each element A of G there exists a **reciprocal** (or inverse) element A^{-1} of G such that $A^{-1}A = E$.

Groups which have special properties are often given special names; see **Abelian group** and some of the following entries.

GROUP, ALTERNATING. A **group** which contains the even **permutations** of n objects; its order is $n!/2$; and it is a **subgroup** of the **symmetric group** of order $n!$.

GROUP, CONTINUOUS. A **group** with a non-denumerable infinity of elements. An infinite group whose elements are denumerable is a discrete group.

GROUP, CYCLIC. An **Abelian group** formed from a single element A and its integral powers: $A, A^2, A^3, \cdots, A^{n-1}, A^n = E$, where E is the **unit element.**

GROUP-DIFFUSION METHOD. A theoretical treatment of nuclear **reactors** in which it is postulated that the energy of the neutrons, from the source energy (fission) to thermal energy, can be divided into a finite set of energy intervals, or groups. Within each group the neutrons are assumed to diffuse without energy loss until they have suffered the average number of collisions required to decrease their energy to that of the next lower group.

GROUP, DIHEDRAL. The **group** consisting of the elements $C^n = E$, $S^2 = E$, $SC = C^{-1}S$, designated by $\mathbf{D}_n$ and of order $2n$. Consider a regular polygon in the XY-plane with coordinates of the n corners $x_k = r \cos 2\pi k/n$, $y_k = r \sin 2\pi k/n$, $k = 0, 1, \cdots, (n-1)$. The proper rotations of this object through $2\pi/n$, indicated by $C(\phi)$, and the improper rotations, $S(\phi)$, which transform the polygon into itself constitute $\mathbf{D}_n$.

GROUP, DISCRETE. See **group, continuous.**

GROUP DISPLACEMENT LAW. See **radioactive displacement, law of.**

GROUP, FACTOR. See **group, quotient.**

GROUP, FINITE. A **group** containing a finite number of elements n. Its **order** is therefore also n.

GROUP, FULL LINEAR. The collection of all non-singular **matrices** of order n, with matrix multiplication as the law of combination. Its order is infinite since its elements are the infinite number of linear transformations of one **vector** into another.

GROUP, INFINITE. Containing an infinite number of **elements.** (See **group, continuous.**)

GROUP MODULATION. In telephone carrier circuits and in radio links of telephone circuits, the treatment of several carrier **channels** as a single group and the **modulation** of the whole upon a new **carrier.** In the reception of such a system, of course, the received signal must first be demodulated into the various channels, and then in another step each channel must be demodulated to obtain the original voice currents.

GROUP, ORTHOGONAL. A **subgroup** of the **unitary group,** its elements are all real n-dimensional square **unitary matrices.** The determinant of these matrices is ± 1; if $+1$, they are proper orthogonal matrices, if -1, improper orthogonal matrices. The subgroup of the orthogonal group containing only proper orthogonal matrices is the **rotation group** of order n. If $n = 3$, the proper orthogonal matrices correspond to rotations about an axis passing through the origin, while the improper matrices correspond to such rotations, followed by reflections in a plane perpendicular to the axis of rotation. These conceptions may be generalized for n-dimensions and specialized for two dimensions.

GROUP, PERMUTATION. Its elements are the various **permutations** or rearrangements of a standard arrangement of symbols or objects. A typical element is

$$S = \begin{pmatrix} s_1 & s_2 & \cdots & s_n \\ 1 & 2 & & n \end{pmatrix},$$

meaning that the operation S replaces 1 by s_1, 2 by s_2, etc. (See **group, alternating; group, symmetric.**)

GROUP, QUOTIENT. Suppose H is an invariant **subgroup** of a **group** G and that HX, HY, $\cdots$ are its **cosets.** The **quotient** (or **factor**) **group,** frequently designated by G/H, is **isomorphous** with G. Its **unit element** is H and its remaining elements are the cosets.

GROUP, ROTATION. See **group, orthogonal.**

GROUP, SYMMETRIC. The group of all **permutations** of n letters or objects. Its **order** is $n!$.

GROUP THEORY. Study of the **algebra** and other mathematical properties of **groups.**

GROUP, UNITARY. A **subgroup** of the **full linear group,** it contains all n-dimensional square **unitary matrices.**

GROUP VELOCITY. (1) The velocity of propagation of the crest of a group of interfering waves where the component wave trains have slightly different individual frequencies and phase velocities. In a **dispersive medium** in which the **phase velocity** V is a function of the frequency f, the group velocity U has the form

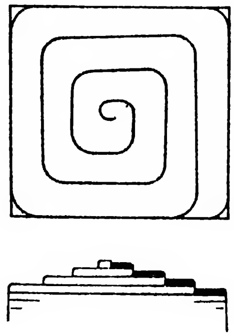
$$U = \frac{V_0}{1 - \frac{f_0}{V_0}\left(\frac{dV}{df}\right)_0}$$

where V_0 is the mean phase velocity of the component wave trains, f_0 the average frequency in the group and $\left(\frac{dV}{df}\right)_0$ is the value of the derivative taken at the average frequency.

(2) The Institute of Radio Engineers definition of group velocity is as follows: Of a traveling plane wave, the velocity of propagation of the envelope of a wave occupying a frequency band over which the envelope delay is approximately constant. It is equal to the reciprocal of the rate of change of **phase constant** with **angular frequency.** Group velocity differs from phase velocity in a medium in which the **phase velocity** varies with frequency.

GROWTH CURVE. (1) An **activity curve** in which the activity increases with time, or that portion of an activity curve showing such an increase. (2) A theoretical or experimental curve showing, as a function of time, the number of atoms, or the mass, or the activity of a nuclide being produced in a **radioactive transformation** or in an **induced nuclear reaction.**

GROWTH SPIRAL. A structure observed on the surfaces of crystals, after growth. In its ideal form, it consists of a **growth step** winding in an Archimedean spiral ($r = a\theta$) from the center downwards and outwards to the edge of the crystal, and is evidence of the growth of the surface about a **screw dislocation.** In some cases the spiral may be distorted so that the step follows certain preferred crystallographic directions, with sharp corners, especially after very rapid growth. (See figure.)



Step formation during crystal growth (after F. C. Frank)

GROWTH STEP. A ledge, one or more lattice spacings high, on the surface of a crystal, where **crystal growth** may take place. In growing, the ledge moves over the surface, leaving a new layer of atoms behind it.

GRÜNEISEN CONSTANT (OR GRÜNEISEN GAMMA). The constant γ occurring in the relation connecting the linear expansion coefficient β with the compressibility K and the specific heat C_V, i.e.,

$$\beta = K\gamma C_V/3V$$

where V is the volume. This relation is reasonably well satisfied for cubic crystals. According to the theory by which it is deduced,

$$\gamma = -\frac{V}{\Theta}\frac{d\Theta}{dV},$$

where Θ is the **Debye temperature.**

GRÜNEISEN FORMULA. An empirical formula for the variation of the **electrical resistivity** of a very pure metal with temperature, of the form

$$\rho \propto TG(\Theta/T)$$

where

$$G(x) = x^{-4}\int_0^x \frac{s^5 ds}{(e^s - 1)(1 - e^{-s})}.$$

There is good theoretical justification for a formula of this type, but the parameter Θ

should not be taken literally as a measure of the **Debye temperature.**

GUARD BAND. A narrow band of unassigned frequencies between assigned channels designed to prevent interference between stations occupying these channels In television broadcasting, for example, the band is 0.25 megacycles in most instances.

GUIDED WAVE. See **wave, guided.**

GUSETRON. Same as **gausitron.**

GUSTS. Transient but rapid fluctuations of wind velocity. Gusts are the result of turbulent air flow. Gusty winds usually vary radically in direction.

GYRATOR CIRCUIT. See **circuit, gyrator.**

GYROCOMPASS. Any **compass** which depends for its action on the conservation of the angular momentum of a spinning body. (See **gyroscope.**) In the usual gyrocompass, a motor-driven wheel is mounted on an axis in gimbals. The combined use of friction and of a gravitational restoring torque insure that the equilibrium position of the axis of rotation is along the north-south horizontal line, so the gyrocompass indicates true north regardless of the orientation in which it is started.

GYROMAGNETIC EFFECT. When a substance is magnetized, it acquires a certain amount of angular momentum. Because the magnetic moment of each electron is associated with its **spin** or **orbital angular momentum**, changing the total magnetic moment requires a change in the total angular momentum. The effect is small, but can be measured for **ferromagnetic** substances, either by the **Barnet** or **Einstein-de Haas** method. (Also see discussion of **magnetostriction.**)

GYROMAGNETIC RATIO. (1) The ratio of the magnetic moment of a system to its angular momentum. (See **gyromagnetic ratio, nuclear.**) (2) The ratio of moment of momentum to magnetic moment. An electron traveling around a circular orbit f times per second generates a magnetic moment equal to the product of the orbit area and the equivalent current:

$$m_0 = ef\pi r^2/c.$$

Since the charge is negative, the mechanical momentum is in the opposite direction and has the magnitude

$$J_0 = 2\pi fmr^2,$$

yielding the gyromagnetic ratio, for orbital motion

$$g_0 = \frac{J_0}{m_0} = \frac{2mc}{e}.$$

The factor c disappears throughout when mksa units are used. For an electron spinning about its own center, the quantum-theory values of magnetic and mechanical momentum yield

$$g_s = \tfrac{1}{2}g_0 = \frac{mc}{e}.$$

GYROMAGNETIC RATIO, NUCLEAR. The ratio of the magnetic moment of the nucleus, μ, to the nuclear angular momentum quantum number, I. (See **nuclear magnetic resonance.**)

GYROSCOPE. A heavy symmetrical disk free to rotate about an axis which itself is confined within a framework such that it is free to take any orientation in space. If the disk is set spinning, the direction of its axis of rotation will remain fixed in space no matter what motion the outer framework undergoes. Gyroscopes are used to provide fixed reference directions for such instruments as the **gyrocompass** on ships, the similar gyro-steering mechanism in a torpedo and the orientation indicators of an aircraft.

H

H. (1) Planck constant (h). (2) Dirac h ($\hbar$). (3) The gauss (H). (4) Magnetic intensity, magnetic force, or magnetizing force (**H**). (5) The henry or Henry law constant (H). (6) Height, depth or thickness (h). (7) Hour (h). (8) Hamiltonian function or operator (H). Perturbing Hamiltonian function or operator ($\mathcal{H}$). (9) Heat of phase change, total (ΔH), per atom or molecule (Δh or Δh_m), per mole (ΔH, ΔH_M or Δh), per unit mass (Δh). (10) Enthalpy, total (H), per atom or molecule (h or h_m), per mole (h, H or h_m), per unit mass (h). (11) Boltzmann function (H). (12) Humidity (H). (13) Degree of electrolysis or hydrolysis (h). (14) Miller index (h, k, l). (15) Hydrogen (H). (16) Radius of lens zone (h). (17) Altitude (h). (18) Hydrodynamic head (h) (19) Radiant flux density (H). (20) In spectroscopy, hazy, diffuse or nebulous (h), very hazy, diffuse or nebulous (H). (21) Nuclear-spin hyperfine structure (hfs) (22) Type of electron with an azimuthal quantum number of 5 (h). (23) Spectral term-symbol for L-value of 5 (H). (24) Circuit-diagram symbol for heater-connection on vacuum tubes.

H AND D CURVE (HURTER AND DRIFFIELD CURVE). A characteristic curve of a photographic emulsion which is a plot of **density** against the logarithm of **exposure.** It is used for the control of photographic processing, and for defining the response characteristics to light of photographic emulsions. (See **gamma.**)

***h*-BAR OR $\hbar$.** Symbol for Dirac-h, the universal constant $h/2\pi$, where h is the **Planck constant.**

H-LINES. A contour along which the electromagnetic **field strength** is constant with respect to some reference plane.

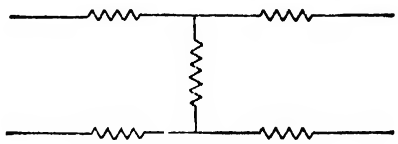
H NETWORK. See **network, H.**

***h*-PARAMETER.** See **transistor, parameters, h_{11}, h_{12}, h_{21} and h_{22}.**

H-PLANE BEND. For a rectangular uniconductor **waveguide** operating in a **dominant mode,** a bend in which the longitudinal axis of the guide remains in a plane parallel to the plane of the magnetic field vector throughout the bend.

H-PLANE TEE JUNCTION. See **junction, H-plane tee.**

H SECTION. In many circuits, particularly in the telephone field, it is necessary to have both sides of a circuit balanced to **ground** to reduce the effect of interfering influences (see **inductive interference**) This is accomplished by dividing any series impedance into two



H section

equal parts and inserting one in each line, rather than putting the total amount in one line. (See figure.) (See also **network, H.**)

***H*-THEOREM.** The **entropy** of a system always increases, as concluded by Boltzmann from his calculations of the kinetics of ideal gases. Boltzmann defined a function H by the equation:

$$H = N_0 \int \ln f \cdot f \, d\xi \, d\eta \, d\zeta \, dV$$

where N_0 is the number of molecules, f is the **distribution function** for all the molecules, ξ, η, and ζ are components of the molecular velocity, and V is the volume. He demonstrated that H is a quantity which decreases in all possible processes involving deviations from the equilibrium value of f, and is therefore analogous to negative entropy.

H WAVE. A transverse electric wave. (See **wave, transverse, electric.**)

HAFNIUM. Metallic element. Symbol Hf. Atomic number 72.

HAIDINGER FRINGES. Interference fringes seen with thick, flat plates near normal incidence. The fringes of the **Fabry-Perot interferometer** are of this type. They are also known as constant angle or constant deviation fringes.

HAIL. Stones of ice ranging from about $1/16''$ in diameter to as much as 4 or 5″. Hail stones are often transparent, but more frequently translucent, being formed of alternate layers of clear and opaque ice. Hail usually falls from **thunderstorms.**

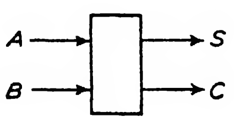
HAIL (SMALL). Small ice particles consisting of a nucleus of soft hail with a shell of ice about it. They do not rebound when striking a hard surface, are not compressible or crisp. Usually small hail is wet, and falls at a temperature near or slightly above 32°F.

HAIR TUNING BAR. A hairpin-shaped metal bar used to vary the electrical length of a dipole antenna (see **antenna, dipole**) without changing the position of the elements. The bar serves as a variable electrical-strength, interconnector bar for the elements.

HALATION. See discussion of **antihalation backing.**

HALF-ADDER. A circuit having two input and two output channels for binary signals (0,1) and in which the output signals are related to the input signals according to the following table:

Input to		Output from	
A	*B*	*S*	*C*
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1



Half-adder

(This circuit is called a half-adder because two such circuits form one **adder.**)

HALF-CELL. An **electrochemical** system consisting of a single **electrode** and an electrolytic solution, with usually a (reversible) **ionization** process in progress between electrode and electrolyte.

HALF-LIFE. The time required for disintegration of one-half the atoms of a sample of a radioactive substance. Its relation to the **disintegration constant** and the **mean life** is as follows:

$$t_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda} = 0.693\tau$$

where $t_{1/2}$ is the half-life, λ is the disintegration constant and τ is the mean life.

HALF-LIFE, BIOLOGICAL. The time in which a living tissue, organ or individual eliminates, through biological processes, one-half of a given amount of a substance, often a radioactive substance, which has been introduced into it.

HALF-LIFE, EFFECTIVE. Half-life of a radioactive isotope in a biological organism, resulting from the combination of radioactive decay and biological elimination.

Effective half-life

$$= \frac{\text{Biological half-life} \times \text{Radioactive half-life}}{\text{Biological half-life} + \text{Radioactive half-life}}.$$

HALF-POWER WIDTH OF A RADIATION-LOBE. In a plane containing the direction of the maximum of the **lobe,** the full angle between the two directions in that plane about the maximum in which the radiation intensity is one-half the maximum value of the lobe.

HALF-SHADE PLATE. A semicircular, half-wave plate (see **elliptically-polarized light**) of quartz set between the **polarizer** and **analyzer** and close to the former. Useful in making precision settings with a polariscope. (See also **prism, Cornu-Jellet.**)

HALF SILVERED. A surface coated with a metallic film of such thickness that it transmits approximately half of the light falling on it at normal incidence and reflects approximately half is said to be half silvered.

HALF-STEP. See **tone, semi-.**

HALF-THICKNESS. The thickness of a particular absorber that will reduce the intensity of a beam of radiation to one-half its initial

value. If the absorption is exponential, the half-thickness is related to the linear or mass **absorption coefficient** and the mean free path as follows:

$$d_{1/2} = \frac{\ln 2}{\mu} = \frac{0.693}{\mu} = 0.693l$$

where $d_{1/2}$ is the half-thickness, μ is the absorption coefficient and l is the mean free path.

HALF-VALUE PERIOD. See **decay coefficient.**

HALF-WAVE PLATE. See **elliptically-polarized light.**

HALF-WAVE RECTIFIER. See **rectifier, half-wave.**

HALFWIDTH. If $y = f(x)$ is a function such that it has a maximum y_m at x_m and falls off rapidly on each side of this maximum, the halfwidth of the function is the difference $x_2 - x_1$ between the two values of x for which $y = y_m/2$; e.g., the halfwidth of the **error function** integrand e^{-y^2} is 1.67.

HALFWIDTH OF A SPECTRAL LINE. The intensity within a spectral line may be expressed as $I(x)$, where x is a measure of **wavelength, frequency** or **wave number,** and where $I(x)dx$ is a measure of the contribution to the intensity between x and $x + dx$ The **halfwidth** of the line is the halfwidth of the function $I(x)$.

HALL ANGLE. The ratio of the electric field E_y, developed across the current, to the field E_x, generating the current, in the magnetic field H_z, as a result of the **Hall effect.**

HALL COEFFICIENT. The measure of the **Hall effect is**

$$R_H = \frac{E_y}{j_x H_z}$$

where E_y is the electric field developed in the y direction when a current of current density j_x flows in the x direction through a magnetic field H_z in the z direction According to the **free electron theory of metals,** the Hall coefficient should be given by

$$R_H = \frac{1}{Nce}$$

where N is the number of free electrons per unit volume, of charge e (in esu), and c is the velocity of light. The observed result that for some metals the **carriers** would seem to have positive charges is explained by the **band theory of solids.** In a nearly filled band the wave functions of the electrons near the top of the band are so modified that it is the **holes** in the band that behave like particles. Since a hole represents the absence of negative charge, it behaves as if positively charged.

HALL CONSTANT. See **Hall coefficient.**

HALL EFFECT. The development of a transverse, electric potential-gradient in a current-carrying conductor upon the application of a magnetic field. (See **Hall coefficient.**)

HALL MOBILITY. The **mobility** of electrons or **holes** in a **semiconductor** as measured by the **Hall effect.** It is given by

$$\mu_H = c\theta/H_z$$

where θ is the **Hall angle** in the magnetic field H_z, and c is the velocity of light.

HALLWACHS EFFECT. A name for the **photoelectric effect** whereby a negatively-charged body in a vacuum is discharged by irradiating it with ultraviolet light.

HALO. (1) A faint colored ring seen about a light source as viewed through light clouds or fog The size of the ring depends on the size of the scattering particles. A halo is not a rainbow. (2) A ring surrounding a **photographic image** of a bright source, due to light being scattered in any one of several possible ways.

HALOGEN. A member of the seventh group of elements i.e., those lacking just one electron to make a closed outer shell. These elements are fluorine, chlorine, bromine, iodine and astatine.

HAMILTON PRINCIPLE. A variation principle which, in general form, states that the motion of a mechanical system can be expressed by the equation

$$\int_{t_1}^{t_2} (\delta K + \sum_{i=1}^{n} \mathbf{F}_{ie} \cdot \delta \mathbf{r}_i) dt = 0$$

where δK is the variation in kinetic energy and $\sum_{i=1}^{n} \mathbf{F}_{ie} \cdot \delta \mathbf{r}_i$ is the **virtual work** done by all the impressed external forces. If the impressed

forces form a conservative system with potential energy V, the principle takes the form

$$\int_{t_1}^{t_2} \delta(K - V)dt = 0$$

where $K - V = L$, the **Lagrangian function.** It should be emphasized that the variations in all quantities (represented by δK or δL, etc.) must vanish at the time instants t_1 and t_2, i.e., all varied paths implied in the principle must correspond to the same time interval.

For a conservative system the principle may be stated: the time integral of the Lagrangian function has a stationary value for the actual path compared with all other possible paths having the same end-points and performed in the same time. In most cases encountered in practice the stationary value is a minimum.

HAMILTONIAN FUNCTION. (1) In classical particle mechanics, a function of n generalized coordinates q_i and momenta p_i commonly symbolized by H and defined by:

$$H = \sum_{1}^{n} p_i\dot{q}_i - L$$

where p_i is the momentum of ith particle, $\dot{q}_i$ is the first time derivative of ith **generalized coordinate,** L is a **Lagrangian function.**

If the Lagrangian function does not contain the time explicitly, H is equal to the total energy of system.

H satisfies the canonical equations of motion

$$\frac{\partial H}{\partial p_i} = \dot{q}_i, \qquad \frac{\partial H}{\partial q_i} = -\dot{p}_i.$$

(2) In quantum theory, an operator H which gives the equation of motion for the wave function ψ in the form:

$$i\hbar\frac{\partial \psi}{\partial t} = H\psi.$$

(See **Lagrangian function; canonical equations of motion.**)

HAMMER TRACKS. Tracks produced in nuclear emulsions which are attributed to the expulsion of a Li^8 nucleus from a heavier nucleus as a result of cosmic ray bombardment. The Li^8 is radioactive and undergoes β-decay with a half-life of less than a second to form Be^8; this is unstable and splits instantaneously into two α-particles which are expelled in opposite directions and at right angles to the Li^8 track, thus producing a hammer-like track.

HANGOVER. (1) A fault condition in television and fascimile picture reproduction, in which the signal does not decay as rapidly as dictated by the original signal. Caused by improper **transient response,** the effect is often called tailing. (2) The production of sound from an improperly-loaded loudspeaker for a short time after removal of the driving signal, and due to under-damped oscillations in the mechanical system.

HANKEL FUNCTION. Also called **Bessel functions** of the third kind, the Hankel functions are of two kinds:

$$H_n^{(1)} = i \csc n\pi[e^{-n\pi i}J_n(x) - J_{-n}(x)];$$

$$H_n^{(2)} = -i \csc n\pi[e^{n\pi i}J_n(x) - J_{-n}(x)]$$

where $J_n(x)$ is a Bessel function. Equivalent definitions are $H_n^{(1,2)}(x) = J_n(x) \pm iN_n(x)$, where $N_n(x)$ is a **Neumann function.** If n is not an integer or zero, a general solution of the **Bessel differential equation** is

$$y = AH_n^{(1)} + BH_n^{(2)}$$

with A, B as the two integration constants.

HANKEL TRANSFORM. Provided certain conditions are satisfied, $f(y)$ is the **Hankel transform** of $F(x)$ and of order n:

$$f(y) = \int_0^\infty J_n(xy)F(x)xdx;$$

$$F(x) = \int_0^\infty J_n(xy)f(y)ydy$$

where J_n is a **Bessel function.**

HARCOURT LAMP. See **lamp, Harcourt.**

HARDNESS. The property of firmness or resistance possessed by solids and very viscous liquids. The degree of hardness of a substance is shown by its resistance to cutting, scratching, or abrasion. Hardness also means the presence in water of certain salts which form insoluble deposits in boilers, which form precipitates with soap, and which have other objectionable effects.

HARDNESS, BIERBAUM. The relative hardness of a micro-constituent of an alloy,

determined by an instrument called the Bierbaum microcharacter. The method involves the measurement of the width of a scratch produced by a standard diamond point, under a standard pressure.

HARDNESS, BRINNELL. A measure of the relative hardness of the surface of a substance, obtained by measuring the depth of indentation of a standard steel ball at a standard pressure; and then computing the hardness by an expression whereby the value obtained is directly proportional to the applied pressure, and inversely proportional to the depth of penetration.

HARDNESS, ROCKWELL. A measure of relative hardness of the surface of a substance, based on the indentation made by a $\frac{1}{16}''$, $\frac{1}{8}''$ or $\frac{1}{4}''$ standard steel ball, or a conical diamond with an apex angle of 120°. The results are reported by using numbers to denote the load in kilograms, and letters to denote the ball or diamond producing a given indentation.

HARDNESS SCALE, MOH. A system in which all solid substances are classified in order of increasing hardness, so that the hardness of any particular substance may be expressed by a number. The numbers were established by assigning the integers from one to ten to arbitrarily chosen substances of increasing hardness, ranging from talc which was given the number one, to diamond which was given the number ten. This was the original Moh scale and is still generally used. In the new Moh scale, fifteen substances are used, and diamond has the number fifteen. The hardness of any substances not on the scale is determined by the scratch test, i.e., by comparing its hardness with that of the various substances in the standard scale, utilizing the principle that the harder of the two substances will scratch the softer one, and will not be scratched by it. When a substance is found to have hardness between two of the standard substances in the scale, this fact is expressed by use of decimal notation. Thus, the mineral having hardness of 6.65 would be harder than feldspar 6, and softer than quartz 7.

The original Moh's scale assigned the integral numbers as follows: 1—Talc; 2—Gypsum; 3—Calcite; 4—Fluorite; 5—Apatite, 6—Orthoclase; 7—Quartz; 8—Topaz; 9—Corundum; 10—Diamond. In the new Moh's scale the numbers above five have been reassigned as follows: 6—Orthoclase, Periclase; 7—Vitreous Pure Silica; 8—Quartz, Stellite; 9—Topaz; 10—Garnet; 11—Tantalum Carbide, Fused Zirconia; 12—Tungsten Carbide, Fused Alumina; 13—Silicon Carbide; 14—Boron Carbide; 15—Diamond.

HARDNESS SCALE, SHORE. A scale of relative hardness based on the elastic rebound of a heavy plummet, with a standard hard point, which is dropped on the surface of the specimen from a fixed height.

HARMONIC. (1) A solution of **Laplace's equation.** An infinite number of harmonic functions satisfy the conditions and in general they are **transcendental.** The most familiar ones are **solid spherical harmonics** which are **homogeneous** in the variables x, y, z. A **spherical surface harmonic** is the special set taken on the surface of a unit sphere and usually given in **spherical polar coordinates.** The angular dependent parts can be taken as

$$Y(\theta,\phi) = \begin{pmatrix}\cos m\phi \\ \sin m\phi\end{pmatrix} P_n{}^m (\cos \theta),$$

where $P_n{}^m$ is the **associated Legendre polynomial.** The surface harmonic is **tesseral** if $m < n$; **sectoral,** if $m = n$; **zonal,** if $m = 0$.

When Laplace's equation is solved in other curvilinear coordinate systems, the solutions are also called harmonics. Examples are **cylindrical harmonics** or **Bessel functions; ellipsoidal harmonics** or **Lamé functions; toroidal harmonics** or **Hicks functions.**

(2) In physical terms, a harmonic is a sinusoidal quantity having a frequency which is an integral multiple of the fundamental frequency of a periodic quantity to which it is related. For example, a wave, the frequency of which is twice the fundamental frequency, is called the second harmonic.

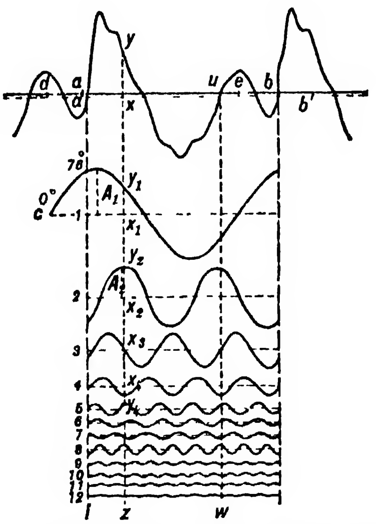
(3) In musical terms, a harmonic is a partial whose frequency is an integral multiple of the fundamental frequency. (See **frequency, fundamental.**)

HARMONIC ANALYSIS. Not only is it possible to combine two or more simple **harmonic motions** of different period, amplitude, and phase to form a complex motion, but there are also means of analyzing the resultant motion, when the latter is given, to find its component harmonics. For example, if the wave form

of such a complex tone as that produced by a bell or a saxophone is accurately graphed by means of a phonodeik (see **vibrations and waves,** and **musical sounds**), the equation of the vibratory motion can be deduced in such form as to show the separate components. Fourier showed that the same analysis is possible for any periodic motion, however complicated. The equation, called the **Fourier series,** may be written

$$y = a \sin 2\pi nt + b \cos 2\pi nt + c \sin 4\pi nt$$
$$+ d \cos 4\pi nt + e \sin 6\pi nt + f \cos 6\pi nt + \cdots,$$

in which y is the displacement of the vibrating particle and t is the time. The fundamental frequency n and the constants a, b, c, d, etc., must be calculated from the given wave form or the data from which it is plotted. There is a type of instrument, called a "harmonic analyzer," which automatically com-



Records of a complex sound and 12 of its components (after D. C. Miller)

putes the coefficients; or it may be done mathematically, though the process is very laborious. The accompanying figure shows the wave form and the twelve components of a complex tone, analyzed by Professor D. C. Miller.

HARMONIC ANALYZER. A machine for analyzing a periodic function into the harmonic components of a **Fourier series** representation.

HARMONIC BAND. See **band, second harmonic; band, third harmonic.**

HARMONIC CONVERSION TRANSDUCER. See **transducer, harmonic conversion.**

HARMONIC DISTORTION. See **distortion, harmonic.**

HARMONIC MOTION. A distinct type of periodic motion, or vibration, characteristic of elastic bodies; illustrated by a bird-cage bobbing up and down at the end of a spiral spring, or (approximately) by the piston of a steam engine. It may be either simple, with only one **frequency** and amplitude, or made up of two or more simple components and consequently of more complex character. The essential feature of simple harmonic motion is that, with its range extending to equal distances on both sides of an equilibrium position or origin, the **acceleration** is always toward the origin and directly proportional to the distance from it. With elastic vibrations this is easily seen to follow from Hooke's law, since the force tending to restore the deformed body to equilibrium is proportional to the deformation. The motion is called "harmonic" undoubtedly because the vibrations of bodies emitting musical sounds are of this character. Any simple harmonic motion may be represented by the equation

$$y = a \cos (2\pi nt + \phi),$$

in which y is the distance at time t, a is the amplitude, n is the frequency or number of vibrations per unit time, and ϕ is the phase constant, such that when $t = 0$, $y = a \cos \phi$.

It is interesting to note the relationship between harmonic and circular motion. If a peg is inserted in the face of a circular disk or wheel and the latter uniformly rotated, the motion of the peg, as viewed with the wheel seen edgewise, is simple harmonic. In fact, uniform circular motion is made up of two simple harmonic components of the same period and amplitude at right angles, one being a quarter-period ahead of the other in phase. If the two harmonic components have a phase difference other than a quarter-period, the resultant in general is motion in an ellipse; while if they have unequal periods, the path is one of a class of more or less complicated loci called "Lissajous' curves."

HARMONIC MOTION, DAMPED. The differential equation of a system which will oscillate with a **harmonic motion** is

$$M \frac{d^2x}{dt^2} + kx = F(t),$$

where M is the mass of the moving particle, k is the restoring force constant, x is the instantaneous displacement and $F(t)$ is the external force applied to the mass. If frictional forces or other dissipative agencies act, the behavior of the system may often be approximated closely by the equation

$$M \frac{d^2x}{dt^2} + R\frac{dx}{dt} + kx = F(t)$$

where R is a constant. (See **oscillation, damped harmonic; oscillation, forced.**)

HARMONIC MOTION, PERIOD OF. The time for one complete oscillation, that is, the reciprocal of the **frequency.**

HARMONIC MOTION, SIMPLE ELLIPTIC. A compounded oscillatory motion consisting of (simple) **harmonic motion** in two fixed perpendicular directions with equal frequencies. The resultant trace of the motion is in general an ellipse, which depending on the relative phase and amplitudes of the two components may take the special form of a circle or straight line.

HARMONIC OPERATION, IMPEDED (CONSTRAINED MAGNETIZATION, FORCED MAGNETIZATION). That type of operation which takes place in a **magnetic amplifier** in which the impedance of the control circuit and any circuit closely coupled to it is so great as to substantially prevent the flow of all harmonic currents in such circuits.

HARMONIC OPERATION, UNIMPEDED (NATURAL MAGNETIZATION, FREE MAGNETIZATION). That type of operation which takes place in a **magnetic amplifier** in which the impedance of the control circuit or any circuit closely coupled to it is so small as to permit substantially unimpeded flow of all harmonic currents in such circuit.

HARMONIC OSCILLATOR. Any system including one or more parts which undergo **harmonic motion,** damped or undamped, after being disturbed.

HARMONIC PROGRESSION. The sequence a, b, c, $\cdots$ if their reciprocals $1/a$, $1/b$, $1/c$, $\cdots$ form an **arithmetic progression.** The harmonic mean between two numbers is the middle term of a harmonic progression whose first and last terms are the given numbers. The harmonic mean between a and b is given by $H = 2ab/(a + b)$. If A, G, and H are respectively the arithmetic, geometric, and harmonic mean of two numbers then $G^2 = AH$.

HARMONIC SERIES OF SOUNDS. A series of sounds in which each basic frequency in the series is an integral multiple of a fundamental frequency. (See **frequency, basic** and **frequency, fundamental.**)

HARMONICS, SUPPRESSED. See **saturable reactor; high-control impedance.**

HARRIS FLOW. A type of electron flow in a cylindrical beam in which **space-charge** divergence is overcome through the use of a radial, electric field.

HARTLEY. A unit of information which is generally defined as being equal to 3 219 **bits.**

HARTLEY FORMULA FOR TIME-FREQUENCY DUALITY. As implied by the Fourier integral, a time function cannot be confined within a small region on the time scale when the steady-state transmission characteristic is confined to a narrow range on the time scale. For example, it is well known that, if a telegraph dot is made narrower and narrower, its corresponding significant-frequency spectrum becomes broader and broader until, in the limit when the dot becomes an impulse, its significant-frequency spectrum is of infinite extent. Two mathematical equations which express this relationship are

$$g(t) = \int_{-\infty}^{\infty} c(f) \operatorname{cas} 2\pi ftdf$$

$$c(f) = \int_{-\infty}^{\infty} g(t) \operatorname{cas} 2\pi ftdt$$

where f is the cyclic frequency, t is time, and cas denotes cosine added to sine.

HARTLEY OSCILLATOR. See **oscillator, Hartley.**

HARTLEY PRINCIPLES (WITH REGARD TO INFORMATION CAPACITY OF A TRANSMISSION CHANNEL). The amount of information that can be transmitted is proportional to the width of the frequency range, and the time it is available. Information

content is equated to the total number of code elements, multiplied by the logarithm of the number of possible values a code element may assume. Information content is independent of how the code elements are grouped. By quantizing, the continuous magnitude-time function used in ordinary telephony may be transmitted by a succession of code symbols such as are employed in telegraphy. And, to obtain the maximum rate of transmission of information, the signal elements need to be spaced uniformly.

HARTMANN DIAPHRAGM. Discussed under **Hartmann test.**

HARTMANN DISPERSION FORMULA. A very useful **dispersion formula** which suggests the **anomalous dispersion** near an absorption band, but does not provide for more than one such band and hence can be used over only a limited range of wavelengths It is of the form:

$$n = n_0 + \frac{c}{\lambda - \lambda_0},$$

where n_0, c and λ_0 are empirical constants.

HARTMANN TEST. (1) Hartmann test for **telescope** mirrors For a perfect mirror, light from all points on the mirror should come to the same **focus.** By covering the mirror with a screen, in which regularly spaced holes have been cut, and then permitting the reflected light to strike a photographic plate placed near the focus, the failure of dots on the plate to be regularly-spaced indicates a fault of the mirror.

(2) Hartmann test for **spectrometers.** Light is passed through different parts of the **entrance slit.** Any change in the spectrum as different parts of the slit are used indicates a fault of the instrument A "Hartmann diaphragm" is one device for using only one part of the entrance slit at a time.

HARTREE EQUATION. A relationship credited to D. R. Hartree applicable to magnetrons, which shows the theoretical minimum anode-voltage at which oscillation is possible in the different modes.

This relationship suggests that the rotating field, which has a non-sinusoidal space distribution at any instant, may be expressed as the sum of an infinite number of sinusoidal traveling waves rotating about the cathode with angular velocities

$$\omega = \frac{2mf_n}{Nm + n}$$

where ω is in radians/second; f_n is the frequency of oscillations in the nth mode; N is the number of resonant gaps; n is the mode of oscillation; and m is zero or any integer.

Electrons may transfer energy to or from the field only when they rotate with the same angular velocity which in this case, is a function of d-c anode voltage and axial d-c magnetic field.

The components of the rotating field corresponding to values of m different from zero are called Hartree harmonics.

The lines of constant m and n plotted as a function of d-c anode supply voltage and axial d-c magnetic field are referred to as Hartree lines.

HARTREE HARMONICS. See **Hartree equation.**

HARTREE LINES. See **Hartree equation.**

HARTREE METHOD. See **self-consistent field method.**

HASH. Electrical noise produced by a mechanical vibrator or by the brushes of a generator or motor.

HAÜY LAW. The fundamental law of **crystallography** stating that for a given crystal there exists a set of **axial ratios** such that the intercepts of every crystal plane on the **crystal axes** are expressible as rational fractions of these ratios (See **Miller indices.**)

HAVELOCK LAW. See **Kerr constant.**

HAVERSINE. If θ is an angle, haversine θ = hav θ — ½ vers θ.

HAY BRIDGE. See **bridge, Hay.**

HAZE. Very small particles of salt and dust in the air reduce visibility and cause the atmosphere to appear off-color. Against a dark background the veil appears bluish, and against a bright background it seems yellowish or orange. This is known as dry haze. Very small water droplets cause a haze more grayish than dry haze, known as damp haze or mist.

HEAD. Pressure expressed as the height of the liquid column necessary to develop that pressure at the base. Its use is particularly convenient for considering the flow of the liquid.

HEAD AMPLIFIER. See **amplifier, head.**

HEAD, KINETIC ENERGY. The pressure, possibly expressed as a **head,** equal to the kinetic energy of the fluid flow per unit volume.

HEAD, TOTAL. The **head** measured by a Pitot tube, that is, the sum of the hydrostatic pressure and the kinetic energy head.

HEARING AID. A complete reproducing system, consisting of **microphone, amplifier** and **loudspeaker,** which increases the sound pressure over that normally received by the ear. Vacuum tube amplifiers are gradually being replaced by transistor amplifiers in these devices.

HEARING LOSS (DEAFNESS). At a specified frequency, the ratio expressed in **decibels,** of the threshold of audibility (see **audibility, threshold of**) for a given defective ear to the corresponding threshold for the normal ear.

HEARING LOSS FOR SPEECH. The difference in **decibels** between the speech levels at which the average normal ear and the defective ear respectively reach the same **intelligibility,** often arbitrarily set at 50 per cent.

HEARING LOSS, PER CENT (PER CENT DEAFNESS). At a given frequency, 100 times the ratio of the **hearing loss** in decibels to the number of decibels between the normal threshold levels of audibility and feeling. A weighted mean of the per cent hearing losses at specified frequencies is often used as a single measure of the loss of hearing. The American Medical Association has defined percentage loss of hearing for medicolegal use. (See the *Journal of the American Medical Association* **133,** 396, 397, February 8, 1947.)

HEARING MECHANISM. The entire system of the human ear, consisting of the outer ear (external ear or pinna, and the ear canal terminating in the eardrum), the middle ear (hammer, anvil and stirrup bones which transmit vibrations from the eardrum to the oval window of the inner ear), and inner ear or cochlea (a bony structure of spiral form containing three parallel canals, one of which, the organ of Corti, contains the nerve terminals which are stimulated by vibrations in the cochlea).

HEARING, PER CENT. The per cent hearing at any given frequency is 100 minus the per cent hearing loss (see **hearing loss, per cent**) at that frequency.

HEAT. That heat is a form of **kinetic energy** has been known only since the work of Rumford and Davy in the first decade of the nineteenth century. They succeeded in boiling water and melting ice by heat generated mechanically.

The chaotic agitation of **molecules** which we now associate with heat, and the violence of which determines the temperature, is strikingly exhibited, though on a much altered scale, by the **Brownian movement.** When a substance is heated, its molecules receive impulses which result in the acceleration of their motions of translation, of rotation, and sometimes of internal vibration. With most gases composed of diatomic molecules, a simple calculation based upon the known **specific heat** and upon the **kinetic theory** shows that 60% of the energy, at ordinary temperatures, goes into the translational molecular motion and the other 40% to rotational motion; the internal vibrations apparently do not begin until higher temperatures are reached. This apportionment is in accord with the principle of **equipartition of energy** and the **quantum theory.**

Although we now recognize that heat is energy, it is still customary to express quantity of heat in the old water-temperature measure, by means of **British thermal units** or of **calories**; and whenever heat quantities so expressed are used in thermodynamic calculations, it is necessary to use the **mechanical equivalent of heat** as a conversion factor between these and the ordinary dynamic units of energy (foot-pounds or **ergs**). (See **temperature, calorimetry, thermal convection, thermal conduction, thermal radiation, thermodynamics,** etc.)

HEAT, ATOMIC. The product of the **gram-atomic weight** of an element and its **specific heat.** The result is the atomic heat capacity per gram-atom. For many solid elements, the

atomic heat capacity is very nearly the same, especially at higher temperatures and is approximately equal to $3R$, where R is the **gas constant** (Law of **Dulong and Petit**).

HEAT CAPACITY. The amount of heat necessary to raise the temperature of a system, entity, or substance by one degree of temperature. It is most frequently expressed in calories per degree centigrade. If the mass of a substance is specified, then certain derived values of the heat capacity can be obtained, such as the atomic heat, molar heat, or specific heat. (See **heat, atomic; heat, molecular;** and **heat, specific.**)

HEAT CAPACITY, ELECTRONIC. See **electronic specific heat.**

HEAT CONTENT. A thermodynamic property which may be regarded as the total heat of a substance or system, and is defined as the sum of its internal energy plus the product of its pressure and volume, as in the relationship:

$$H = U + PV$$

where H is the heat content, U is the internal energy (see **energy, internal**), P is the pressure, and V is the volume. Heat content is also called the heat function, and the enthalpy. The form in which this concept enters most commonly into calculations is that of changes in heat content when a system changes from one state to another.

HEAT FLUSH. A method of separating a mixture of He^3 and He^4 by means of a flow of heat in superfluid **helium.**

HEAT IN THE ATMOSPHERE. Heat received from the sun is the primary source of energy for the earth. Some slight amount of heat is received from the earth's interior by virtue of radioactive rocks, but this need not be considered in view of its comparable smallness. Total heat received from the sun, directly below the sun, at the outer limits of the atmosphere (the amount that would be received at the earth's surface if passage were unaffected by the atmosphere and clouds) is very nearly 1.94 gram-calories per sq cm per min. This great quantity of heat is distributed in such a way that the maximum is received directly below the sun with a decreasing amount received as the distance from the heat equator increases. Tropical areas, for this reason, are warm and polar regions cold.

HEAT, LATENT. Heat which is gained by a substance or system without an accompanying rise in temperature during a change of state. (See **heat of fusion, latent; heat of sublimation, latent;** and **heat of vaporization, latent.**)

HEAT, MECHANICAL EQUIVALENT OF. The conversion factor between any unit commonly employed to express mechanical energy and a unit commonly employed to express thermal energy, e.g., 4.1840 joules/calorie.

HEAT, MECHANICAL EQUIVALENT OF, METHODS FOR. See **Callendar and Barnes method; Griffiths method; Jaeger-Steinwehr method; Joule-Rowland method; Laby and Hercus method; Osborne, Stimson and Jennings method; Reynolds and Moorby method; Schuster and Gannon method.**

HEAT, MOLECULAR. (Heat, Molar.) The product of the **gram-molecular weight** of a compound and its specific heat. (See **heat, specific.**) The result is the heat capacity per gram-molecular weight.

HEAT OF ACTIVATION. The increase of **heat content** accompanying the transformation of a substance from a less active to a more reactive form. This process applies commonly to **enzymes,** and to many instances of the **excitation** of atoms or molecules, as well as to the **irradiation** of molecules.

HEAT OF ADSORPTION. The increase of **heat content** when one **mole** of a given substance is adsorbed upon another specified substance. It is also necessary to state whether the **adsorption** is of the van der Waals type or of the activated type, since higher values are obtained from the latter process. Since gaseous adsorption is frequently a function of the pressure, one defines a differential heat of adsorption, as the difference between values of the heat of adsorption at two different neighboring pressures. (See **Langmuir adsorption isotherm.**)

HEAT OF AGGREGATION. The increase of **heat content** accompanying the formation of various aggregates of matter, such as crystals, etc.

HEAT OF ASSOCIATION. The increase of **heat content** when one **mole** of a **coordination compound** is formed from its constituent molecules or other particles.

HEAT OF COMBUSTION. The increase in the **heat content** when one **mole** of a substance undergoes oxidation, whereby the products obtained in complete **combustion** are produced. The heat of combustion is very nearly an additive property; it depends, however, slightly upon molecular constitution, so that isomers do not give identical heats of combustion.

HEAT OF CONDENSATION. The increase of **heat content** when unit mass, or one **mole** of a vapor is converted into liquid at its boiling point under isobaric conditions without change of temperature This quantity is the reverse of the latent **heat of vaporization.**

HEAT OF COOLING. An increase in the **heat content** of a substance or system at certain temperatures on its cooling curve, because of an internal change, commonly to an **allotropic** modification, which produces an increase in heat content. (See **heat of transition.**)

HEAT OF CRYSTALLIZATION. The increase in the **heat content** of one **mole** of a substance attributable to its transformation to the crystalline state

HEAT OF DECOMPOSITION. The change of **heat content** when one **mole** of a compound is decomposed into its elements This is equal in quantity, but opposite in sign, to the **heat of formation.**

HEAT OF DILUTION, DIFFERENTIAL. The increase in **heat content** of a system resulting from addition of an infinitesimal quantity of solvent to the solution

HEAT OF DILUTION, INTEGRAL. The increase in **heat content** occurring when a specified amount of the solvent is added to a solution This quantity is called the integral heat of dilution (or the total heat of dilution) in contrast with the differential heat of dilution.

HEAT OF DISSOCIATION. The increase of **heat content** occurring as a result of the breaking apart of molecules or, in general, in the rupture of valence **linkages.**

HEAT OF FORMATION. The increase of **heat content** of the system when one **mole** of a substance is formed from its elements. If the physical state of the various elements are not specified they are assumed to be in the state at which they would normally exist at atmospheric pressure and ordinary temperature.

HEAT OF FUSION, LATENT. The increase of **heat content** when unit mass, or one **mole** of a solid is converted into a liquid at its melting point (without change of temperature). The value of this quantity is commonly determined at constant pressure.

HEAT OF FUSION (LATENT), METHODS FOR. See **Bunson ice calorimeter method, electrical method,** and **method of mixtures.**

HEAT OF HYDRATION. The increase of **heat content** when one **mole of a hydrate** is formed from the anhydrous form of the compound, and from liquid water.

HEAT OF IONIZATION. The increase of **heat content** accompanying the complete **ionization** of one **mole** of a substance.

HEAT OF LINKAGE. The **bond energy** of a particular valence **linkage** between atoms, as determined by the average amount of energy required to **dissociate** bonds of that type in one **mole** of a given compound. This is illustrated by the case of methane, in which the bond energy of the C--H bond is taken to be one-quarter of the heat required to dissociate one mole of methane into carbon and hydrogen atoms.

HEAT OF NEUTRALIZATION. The increase in **heat content** of a system undergoing a **neutralization** reaction involving molar quantities of reactants

HEAT OF SOLIDIFICATION. The increase in **heat content** upon the formation of one **mole** of a solid from a substance commonly in the liquid state.

HEAT OF SOLUTION, DIFFERENTIAL. A partial differential quantity obtained by differentiating the total heat of solution (see **heat of solution, integral**) with respect to the **molal concentration** of one **component** of the solution, while the concentration of the other component or components, the temperature, and pressure remain constant.

HEAT OF SOLUTION, INTEGRAL. The difference between the **heat content of a solution**, and the heat contents of its **components.**

This quantity is also called the total heat of solution.

HEAT OF SUBLIMATION, LATENT. The increase of **heat content** when unit mass, or one **mole,** of a solid is converted into a vapor under **isobaric** conditions.

HEAT OF TRANSITION. The increase in heat content when one **mole** of a substance changes to an **allotropic** form, at the **transition temperature.**

HEAT OF VAPORIZATION, LATENT. The increase of **heat content** when unit mass, or one **mole,** of a liquid is converted into a vapor at the boiling point, without change of temperature.

HEAT OF VAPORIZATION (LATENT), AT ABSOLUTE ZERO. Quantity appearing in the general vapor-pressure equation (see **vapor pressure, general equation**). It may be defined by the equation

$$\lambda = \lambda_0 + \int_0^T C_g dT - \int_0^T C_s dT$$

where λ is the molar **latent heat of vaporization** of the solid at temperature T, C_g the molar **specific heat at constant pressure** of the vapor, C_s the molar specific heat of the solid, and λ_0 the molar latent heat of vaporization at the absolute zero.

HEAT OF VAPORIZATION (LATENT), METHODS FOR. See **Awberg and Griffiths method; Berthelot condensation method; Henning method; low temperature evaporation method.**

HEAT PROPAGATION IN CONDUCTING MEDIUM. A process governed by the general equation:

$$\nabla^2 T = \frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} = \frac{c\rho}{K}\frac{\partial T}{\partial t}$$

where T is the temperature, c, the specific heat, ρ, the density, K, the thermal conductivity, x, y, z, rectangular coordinates, and t, the time. For the case of radial heat flow (spherical coordinates), the equation is

$$\frac{\partial^2 T}{\partial r^2} + \frac{2}{r}\frac{\partial T}{\partial r} = \frac{\rho c}{K}\frac{\partial T}{\partial t}$$

where r is the radius.

For the case of radial heat flow in one plane (cylindrical coordinates), the equation is

$$\frac{\partial^2 T}{\partial r^2} + \frac{1}{r}\frac{\partial T}{\partial r} = \frac{\rho c}{K}\frac{\partial T}{\partial t}.$$

HEAT PUMP. An apparatus designed to convert mechanical energy into thermal energy, as, for example, by the compression of a gas. The term is coming into increasing use to indicate a device which transfers heat from a colder to a hotter reservoir, with the expenditure of mechanical energy, particularly when the primary purpose is the heating of the hot reservoir rather than the refrigeration of the cool one.

HEAT, SPECIFIC. Also called the specific heat capacity. The quantity of heat required to raise the temperature of unit mass of a substance by one degree of temperature. The units commonly used for its expression are the unit mass of one gram, the unit quantity of heat in terms of the **calorie.**

HEAT, SPECIFIC, AT CONSTANT PRESSURE. The amount of heat required to raise unit mass of a substance through one degree of temperature without change of pressure. Usually denoted by C_p, when the **mole** is the unit of mass, and c_p when the **gram** is the unit of mass.

HEAT, SPECIFIC, AT CONSTANT PRESSURE, METHODS FOR. See **Blackett, Henry and Rideal method; Holburn and Henning method.**

HEAT, SPECIFIC, AT CONSTANT VOLUME. The amount of heat required to raise unit mass of a substance through one degree of temperature without change of volume. Usually denoted by C_v, when the **mole** is the unit of mass, and c_v when the **gram** is the unit of mass.

HEAT, SPECIFIC, AT CONSTANT VOLUME, METHODS FOR. See **explosion method, Joly steam calorimeter, Nernst vacuum calorimeter.**

HEAT TRANSFER. Heat can be transferred by three different methods: by **conduction,** where the heat must diffuse through solid materials or through stagnant fluids; by **convection,** where the heat is carried from one point to another by actual movement of the hot material (common in fluids); and by **radiation,**

where heat is transferred by means of electromagnetic waves.

HEAT TRANSFER, COEFFICIENT OF. The rate of flow of heat through a medium or a system, expressed as the amount of heat passing through unit area, per unit time, and per degree temperature difference. In the **English system** of units, the coefficient of heat transfer is usually expressed in B.t.u. per square foot per hour per degree Fahrenheit

HEAT UNITS, C.G.S. See **calorie.**

HEAT UNITS, ENGLISH. See **British thermal unit.**

HEAT UNITS, MKS. The **joule,** which is also the unit of work: work done by 1 **newton** moving its point of application parallel to itself by 1 meter. One newton is the force required to produce an acceleration of 1 meter/sec^2 in a mass of 1 kilogram. 4.184 joules are equivalent to 1 standard calorie

HEATER. (1) An electric heating element for supplying heat to an indirectly-heated **cathode.** (2) A source of heat for industrial or domestic use. (See **induction heater; induction-conduction heater; hysteresis heater; induction-ring heater,** etc.)

HEATER CURRENT. The current flowing through a **heater.**

HEATER TUBE. See **tube, hot cathode, heater-type.**

HEATER VOLTAGE. The voltage between the terminals of a **heater.**

HEATING, DEPTH OF. In **dielectric heating** usage, the depth below the surface of a material in which effective dielectric heating can be confined when the **applicator** electrodes are applied adjacent to one surface only.

HEATING, DIELECTRIC. See **dielectric heating.**

HEATING, INDUCTION. See **induction heating.**

HEATING PATTERN. The distribution of temperature in a **load** or charge.

HEATING STATION. Location which includes **load coil** or **applicator** and its associated production equipment.

HEATING VALUE. The heating, or calorific, value of a **fuel** is the quantity of heat produced by the combustion, under specified conditions, of unit weight or volume of the fuel.

HEAVISIDE BRIDGE. See **bridge, Heaviside.**

HEAVISIDE-CAMPBELL BRIDGE. See **bridge, Heaviside-Campbell.**

HEAVISIDE LAYER. See **ionosphere.**

HEAVY ATOM METHOD. See **direct x-ray analysis.**

HECTO-. A prefix meaning one hundred.

HECTOGRAM. One hundred **grams.**

HECTOMETER. One hundred **meters.**

HERPOLHODE. The curve along which the cone traced out by the **angular velocity vector** intersects the plane tangent to the **momental ellipsoid** and perpendicular to the angular momentum vector, in the case of a rotating rigid body not subject to any external torque. (See **polhode.**)

"HECTOR SERIES." See **camera lenses.**

HEFNER LAMP. A standard light source which burns amyl acetate and has an intensity of 0.9 U.S. standard **candles** when the flame is at a height of 40 mm.

HEIGHT CONTROL. In television, the control whose setting determines the vertical amplitude of the image

HEIL CIRCUIT. See **Heil oscillator.**

HEIL OSCILLATOR. An early velocity-variation electron device which was a forerunner of the present-day **klystron.**

HEILIGENSCHEIN. A **diffraction** effect seen from considerable altitude due to the reflection of sunlight from dew drops on vegetation.

HEINE FORMULA. An **integral** representation for **Legendre polynomials:**

$$P_n^m(x) = (n+1)(n+2)\cdots(n+m)(-1)^{m/2} \times \frac{1}{\pi}\int_0^\pi [x + \sqrt{x^2-1}\cos\phi]^n \cos m\phi\, d\phi.$$

HEISENBERG EQUATION OF MOTION. According to the quantum theory of a dynamical system described by the **Hamiltonian** H, the time rate of change of an observable represented by the operator X is

$$\dot{X} = \frac{\partial X}{\partial t} - \frac{i}{\hbar}[X, H]$$

where $[X, H]$ is the **commutator** of X and H.

HEISENBERG FORCE. Phenomenologically postulated force between two nucleons derivable from a potential in which there appears an **operator** which exchanges the spins and positions of the two particles.

HEISENBERG PRINCIPLE OF INDETERMINANCY. See **indeterminancy principle.**

HEISENBERG REPRESENTATION. Representation of the equations of motion in **quantum mechanics** and in quantized field theory (see **field theory, quantized**) where the vector describing the state is treated as constant and the time dependence is transferred to the operators which operate on this state vector. This may be represented in **Hilbert space** by keeping the state vector constant and allowing the axes to rotate with time as the motion of the system develops. Matrices representing operators referred to these axes are thus time dependent and obey the **Heisenberg equation of motion.** The theory developed in this representation is therefore called matrix mechanics. (See **Schrödinger representation, interaction representation.**)

HEISENBERG THEORY OF FERROMAGNETISM. The exchange interaction (see discussion of **exchange energy**) between electrons in neighboring atoms can be shown to depend on the relative orientations of the electronic **spins.** If it should turn out that parallel spins are favored, there is a strong tendency for all the spins in the lattice to become aligned, the transition to the ordered state corresponding to the **Curie point.** The concept of localized spins (e.g., d-electrons in the **transition metals**) is confirmed by **neutron diffraction,** but the theory is incomplete at the stage of calculating the actual magnitude and sign of the interaction.

HEISING MODULATION. See **modulation, constant-current.**

HEITLER-LONDON THEORY OF COVALENT BONDING. A treatment of the **exchange forces** between atoms in which the two interacting electrons are assumed to be in **atomic orbitals** about each of the nuclei, these orbitals being then combined into symmetric and anti-symmetric functions. The theory gives a good first approximation to the correct orbitals, but ignores effects such as the possibility of two electrons being simultaneously on the same atom.

HELIOSTAT. An arrangement of mirrors driven by clockwork used to reflect a beam of sunlight in a fixed direction as the sun moves across the sky.

HELIUM. Gaseous element. Symbol He. Atomic number 2. (See also **helium, liquid.**)

HELIUM, LIQUEFACTION. Helium was first liquefied by Kamerlingh Onnes in Leiden in 1908. Onnes used the Linde-Hampson method of liquefaction, in which the cooling, in the lower range, is obtained by the **Joule-Kelvin effect.**

HELIUM, LIQUEFIERS. Besides the Linde-Hampson method used by Kamerlingh Onnes in his first liquefaction of helium, a number of liquefiers have been developed which are based on expansion with external work. Simon has used a very simple device in which helium, cooled to temperatures obtainable with liquid hydrogen, is expanded from 100 or 150 atmospheres to 1 atmosphere. The heat capacity of the pressure cylinder in which the expansion is carried out is very small at these temperatures, and with a single-expansion filling, extremely effective operation can be obtained. Kapitza has developed a reciprocating engine for cooling helium, which has been further improved by Collins. These devices have the advantage that they do not require liquid hydrogen for the liquefaction of helium. Another method due to Simon is based on the cooling obtained when helium gas is desorbed from charcoal.

HELIUM II FILM. Solid surfaces in contact with liquid helium II (see **helium, liquid forms**) are covered with a film of 50 to 100 atoms thickness, along which frictionless flow of liquid can take place.

HELIUM, LIQUID FORMS I AND II. Liquid helium undergoes a change in its physical properties at 2.189°K, the so-called lambda-

point. The form stable between the critical temperature and the lambda-point is called liquid helium I, and that stable between the lambda-point and absolute zero is called liquid helium II. Since the transformation is one of higher order, without latent heat at the lamda-point, the two liquid forms are never co-existent. The lambda-transformation does not occur in liquid helium with the isotopic weight 3.

HELIUM, LIQUID, FRICTION-FREE FLOW IN. The flow of liquid helium II through narrow capillaries or slits is highly independent of pressure head, and of the length of the tube, suggesting freedom from friction. By measuring pressures along the tube, it has been shown that up to a critical velocity which depends on temperature, the flow inside the tube is completely free of friction, all dissipation occurring at the ends of the tube. The complete freedom from friction has also been demonstrated for the **helium film.**

HELIUM, LIQUID, PROPERTIES OF. Liquid helium is a remarkable substance as, owing to its high zero-point energy, it has a very low density and will not solidify under its own saturation pressure. Even at absolute zero, an external pressure of about 25 atmospheres is required for solidification. The density has a maximum at the lambda-point. Whereas helium I has, apart from its low density, most of the properties of a normal liquid, helium II shows a very anomalous behavior. Its viscosity is vanishingly small, and its heat conductivity is much higher than that of any other substance. Moreover, there exists a thermomechanical (fountain) effect. If two vessels containing helium II are connected by a narrow capillary and heat is supplied to one of them, a flow of helium in the direction of the higher temperature will take place. Conversely, in the mechanocaloric effect, a forced flow of helium II through a capillary will result in a cooling of the liquid leaving the capillary. Also, pulses of heat created in the liquid will be propagated in it similarly to density pulses in sound, and the phenomenon has therefore been called second sound. (See also **helium film.**)

HELIUM, LIQUID, SUB-CRITICAL FLOW IN FILMS OF. Mass transport through the **helium II film** takes place at a constant rate which only depends on temperature. It has been shown that in film transport below this critical rate, the flow of mass is completely free of friction.

HELIUM, SOLIDIFICATION. Helium will not solidify under its own vapor pressure down to absolute zero. In order to obtain solid helium the liquid has to be subjected to external pressure (Keesom). The melting pressure, which is about 140 atmospheres at the normal boiling point, has a value of 25 atmospheres at absolute zero.

HELIX. A curve traced on a **cylindrical or conical surface** in such a way that all elements of the surface are cut at a constant angle. A circular helix lies on a right circular cylindrical surface. In **parametric** form, its equation is

$$x = a\cos\theta, \quad y = a\sin\theta, \quad z = b\theta$$

where a, b are constants and θ is a parameter. The thread of a screw is often a circular helix.

HELMHOLTZ EQUATION. An equation of the form

$$n_1y_1\tan\theta_1 = n_2y_2\tan\theta_2,$$

expressing the relation between the linear and the angular magnification at a spherical refracting interface. y_1, y_2 are linear dimensions of object and image, θ_1, θ_2 the angles made by focal rays and axis at **object** and **image points** and n_1, n_2 are **refractive indices** of object and image space. Also called Lagrange-Helmholtz equation. (See, however, the **Abbe sine condition.**) A spherical surface cannot satisfy both these equations for finite angles. Hence a spherical surface can never make a perfect image.

HELMHOLTZ FREE ENERGY. Defined under **free energy (2).**

HELMHOLTZ-KETTELER FORMULA. The **dispersion** formula:

$$n^2 = 1 + \Sigma \frac{D'\lambda^2}{\lambda^2 - \lambda_s^2 + G\lambda^2}$$

where D' is a constant, $G\lambda^2$ is the term representing the frictional force, λ is the wave length and the sum is taken over s, the λ_s being the resonant wave lengths of the medium.

HELMHOLTZ RESONATOR. An enclosure communicating with the external medium

through an opening of small cross-sectional area. Such a device resonates at a single frequency dependent on the geometry of the resonator.

HELMHOLTZ RECIPROCAL THEOREM. See **reciprocity theorem, acoustical.**

HEMERAPHOTOMETER. A type of **photometer** used for measuring **daylight factor.**

HEMICOLLOID. A **colloid** composed of particles of small size, i.e., ranging from 0.005 to 0.0025 micron in length.

HEMIHEDRAL CRYSTALS. See **hemihedrity.**

HEMIHEDRITY. A term describing **crystal** symmetry operations, to indicate that only half of a symmetrical structure undergoes modification. For example, if in truncating a cube the process is carried out symmetrically on four out of the eight solid angles the resulting structure exhibits hemihedral symmetry.

HENNING METHOD FOR LATENT HEAT OF VAPORIZATION. An evaporation method similar to that used earlier by **Griffiths.** Water is evaporated under constant pressure at any temperature between 30°C and 180°C, and the electrical energy needed to evaporate a given amount of water (determined by subsequent condensation) is measured

HENRY. A unit of self or mutual inductance, abbreviation h or hy. (1) The **self-inductance** of a coil in which an emf of one volt is required to change the current at the rate of one ampere per second. (2) The **mutual inductance** of two coils, of such geometry and so arranged that an emf of one volt is induced in one if the current in the other is changing at the rate of one ampere per second. The mutual inductance remains unchanged if the roles of the two coils are interchanged, i.e., if the current is changed in the first and the emf is measured across the second. The millihenry (mh), equal to 0 001 hy, is commonly used as a unit of inductance.

HENRY LAW. The mass of gas dissolved by a given volume of liquid at a given temperature is proportional to the pressure of gas with which it is in equilibrium. The Henry law is strictly true only for ideal solutions (which are approached in their properties by dilute solutions), if the gas is in the same molecular state in the solution as in the gas. Departure from ideal gas behavior also results in deviations from the Henry law. The Henry law and the Raoult law may be shown to be related.

HEPTODE. A seven-electrode **electron tube** containing an **anode,** a **cathode,** a **control electrode,** and four additional electrodes that are ordinarily **grids.**

HERCUS AND LABY METHOD, HEAT TRANSMISSION OF GASES The most satisfactory method of measuring the thermal conductivity of gases. It consists in measuring the temperature gradient across a thin slab of gas of large area of cross section, using a known heat current. The area is defined by two silver-plated circular sheets of copper, one heated electrically, the other cooled by flowing water. Convection effects are eliminated by arranging for the heat flow to take place vertically downwards Lateral heat flow is eliminated by surrounding the hotter plate by a guard ring, and loss of heat in an upward direction, by means of another plate above it, both being maintained at the same temperature as the hotter plate. A temperature difference of about 20°C was used for the original experiments, and a correction of about 5% was necessary for heat transfer by radiation.

HEREDITY, COEFFICIENT OF. See **hereditary mechanics.**

HEREDITARY MECHANICS. The field of mechanics involving boundary conditions extending over continuous intervals of space and time and demanding integrals for their representation For example, in the application of stress to a deformable elastic medium, the final strain at any instant depends not only on the stress at that instant but on the whole previous stress to which the medium has been exposed. Analytically

$$\delta(t) = kX(t) + \int_{t_0}^{t} \theta(t, \tau)X(\tau)d\tau$$

where δ is the final strain at time t, $X(t)$ is the instantaneous stress at time t and the integral represents the effect of the stress heredity of the system. The quantity $\theta(t, \tau)$ is called the coefficient of heredity. The above

equation may be considered an integral equation for the evaluation of X when δ is known

HERING THEORY. A theory of color vision which postulates in the **retina** two mutually exclusive processes (a) anabolism, a building of tissue and (b) catabolism, a breaking down of tissue. It accounts only partly for color blindness.

HERMANN-MANGUIN SYMBOLS. A notation sometimes used to describe the **symmetry classes** of crystals. Two-, three-, four- and six-fold **rotation axes** are represented by the numbers 2, 3, 4 and 6 Three-, four- and six-fold **inversion axes** have symbols 3, 4, 6 Asymmetry has the symbol 1. A **center of symmetry** has the symbol 1. A **plane of symmetry** is represented by m (mirror) The first number denotes the **principal axis.** If a plane of symmetry is perpendicular to an axis, this is represented by n/m (e g , $2/m$, $4/m$, $6/m$) Then follow the symbols for the secondary axes, if any, and then any other symmetry planes

HERMITE EQUATION. A second-order **differential equation**

$$y'' - 2xy' + 2ny = 0; \quad n, \text{ a constant}$$

The **Hermite polynomials** are solutions It occurs in the quantum mechanical problem of the harmonic oscillator. (See also **Weber equation.**)

HERMITE POLYNOMIAL. A solution to the **Hermite differential equation.** The polynomial of degree n is:

$$H_n(x) = (2x)^n - \frac{n(n-1)}{1!}(2x)^{n-2} + \frac{n(n-1)(n-2)(n-3)}{2!}(2x)^{n-4} + \cdots$$

It can also be represented by the relation

$$H_n(x) = (-1)^n e^{x^2} \frac{d^n e^{-x^2}}{dx^n}$$

or by a **generating function.**

HERMITIAN. Describing a matrix for which the elements $A_{ij} = A_{ji}^*$, where the asterisk indicates the **complex conjugate.** If the variables in a **bilinear form** are complex conjugate to each other and if the matrix is Hermitian, the form is also Hermitian. **Linear integral operators** may also be Hermitian

HERPOLHODE. The curve along which the cone traced out by the **angular velocity vector** intersects the invariable plane tangent to the **momental ellipsoid** and perpendicular to the angular momentum vector, in the case of a rotating rigid body not subject to any external torque (See **polhode.**)

HERRINGER-HULSTER EFFECT IN MAGNETRONS. See **phase-focusing.**

HERSCHEL EFFECT. A photographic effect observed first by F. W. Herschel in 1839. Herschel observed that an image on printing-out-paper (silver chloride) is destroyed (bleached out) upon exposure to red light This is now known as the visual Herschel effect The destruction of a latent image in a gelatin emulsion (which must not be dye-sensitized) is now known as the latent Herschel effect Non-color sensitive materials may be made sensitive to the infrared by exposing to red light after exposure

HERTZ. A unit of **frequency** equal to 1 cycle per second

HERTZ ANTENNA. See **antenna, Hertz.**

HESS-IVES PHOTOMETER. A colorimeter using numbered series of colored glass slides to match and designate the color of a substance or solution

HESS LAW. See **constant heat summation, law of.**

HESSIAN. A functional **determinant** defined by the equation

$$H(F) = \frac{\partial(u,v,w)}{\partial(x,y,z)} = \begin{vmatrix} F_{xx} & F_{xy} & F_{xz} \\ F_{xy} & F_{yy} & F_{yz} \\ F_{xz} & F_{yz} & F_{zz} \end{vmatrix}$$

where u,v,w are differential coefficients of another function, $F(x,y,z)$:

$$u = \partial F/\partial x = F_x, \quad v = F_y, \quad w = F_z;$$

$$\partial^2 F/\partial x^2 = F_{xx}, \text{ etc.}$$

(See also **Jacobian** and **Wronskian.**)

HETERODYNE. Two alternating currents of different frequency, when "mixed" in **a** non-linear impedance device such as **a recti-**

fier, generate a current having the sum- and difference-frequencies, either or both of which may be selected by properly tuning or filtering the output. This phenomenon is known as heterodyne action, and is put to practical use in the **superheterodyne radio receiver circuit.**

HETERODYNE CONVERSION TRANSDUCER. See **transducer, heterodyne conversion.**

HETERODYNE DETECTOR. See **beatnote detector.**

HETERODYNE FREQUENCY METER. A frequency measuring device which compares the unknown frequency with a calibrated frequency standard in a **beatnote detector circuit.**

HETERODYNE OSCILLATOR. The **oscillator** in a superheterodyne receiver which provides the frequency required to beat with the signal frequency to produce the correct intermediate frequency.

HETERODYNE WAVEMETER. A **heterodyne frequency meter.**

HETERODYNE WHISTLE. The steady tone heard in the output of an amplitude-modulation receiver due to the beating of two carriers having a small frequency difference.

HETEROION. A complex **ion** consisting of a simpler ion adsorbed upon a molecule. The term is commonly applied in cases where the adsorbing molecule is large, e.g., a protein molecule.

HETEROSTATIC METHOD (OF USE OF QUADRANT ELECTROMETER). See **electrometer, connection of.**

HETEROTOPIC. Having a different **atomic number** or nuclear charge, the opposite of **isotopic.**

HEXAGONAL CLOSE-PACKED STRUCTURE. A **crystal structure** obtained by packing together equal spheres as follows: A layer is made by placing each sphere in contact with six others. A second layer is added by placing each sphere in contact with three spheres of the bottom layer. In the third layer, the spheres go directly above those in the first layer—and so on. (See also **close packed structure.**)

HEXAGONAL SYSTEM. One of the seven **crystallographic systems.**

HEXODE. A six-electrode **electron tube** containing an **anode**, a **cathode**, a **control electrode**, and three additional electrodes that are ordinarily **grids.**

HEYDWEILLER BRIDGE. See **bridge, Heydweiller.**

h-f. Abbreviation for high frequency, which is generally considered to be the band of frequencies between 3 and 30 megacycles per second.

HIGH. A region over which the atmospheric pressure is greater than the surrounding area; an abbreviation for region of high pressure. Anticyclonic winds blow about a high.

HIGH - EFFICIENCY REFLECTING FILMS. In optical instruments it is sometimes desirable to divide a beam of light into two beams of predetermined relative intensity. This can be done by coating glass with a thin film of aluminum. However, in this case for equal reflected and transmitted beams, about 30% of the light is absorbed by the film. By using a thin film of low refractive index, covered by a thin film of high refractive index, the thickness of the films may be adjusted to give the desired reflection and transmission with almost no absorption.

HIGH FIDELITY. The quality of a sound reproducing system such that the acoustical characteristics of the reproduced sounds (usually musical) match as closely as possible the characteristics of the original sounds when made under their normal conditions. Thus a high fidelity reproduction of a symphonic work should sound the same to the listener as if he were present in a concert auditorium, listening to the orchestra directly, even though the sounds used in the recording were actually transcribed in a recording studio with extremely artificial acoustical characteristics.

HIGH-LEVEL MODULATION. See **modulation, high-level.**

HIGH-PASS FILTER. See **filter, high-pass.**

HIGH-PRESSURE CLOUD CHAMBER. See **cloud chamber, high-pressure.**

HIGH-PRESSURE PHENOMENA. The earlier researches in this field were associated with the study of the liquefaction and the **critical states** of gases; for example, the work of Andrews (1861). The critical pressure of water, for example, has a value above 2000 kilograms per cm^2. The hydrostatic pressure at the greatest ocean depths must be about 1000 kilograms per cm^2. But these would now hardly be considered "high" pressures, since with modern technique it is possible to attain pressures as great as 30,000 kilograms per cm^2. The usual means of attaining high pressures is the "intensifier," which is merely a double free piston, that is, a straight rod with a large piston on one end and a small one on the other, each in its own cylinder. Any pressure applied to the larger piston is multiplied in the smaller cylinder by the ratio of the two areas. The chief problem is that of packing to prevent leaks, and this has been met by special devices perfected by Bridgman, Poulter, and others (See **pressure gauges.**)

Substances often exhibit unfamiliar properties at high pressure For example, the minimum volume of water, at 4°C under normal pressure, occurs at lower and lower temperatures as the pressure is increased; and finally, at about 2500 kilograms per cm^2, a minimum no longer exists. Solid bismuth kept at 250°C melts at a pressure of 5600 kilograms per cm^2; but liquid sodium at 150°C solidifies at 7200 kilograms per cm^2. Some oils behave like sodium, so that they cannot be used as the media in high-pressure apparatus. The thermal expansion of liquids under great pressure decreases with temperature instead of increasing as it normally does. When liquids are subjected to 12,000 kilograms per cm^2, the work of compression causes them to become almost boiling hot. Many other properties have been studied in detail, such as density, electrical resistance, thermal conductivity, viscosity, dielectric constant, and polymorphic transitions.

HILBERT SPACE. Space defined by a set of orthonormal functions ϕ_i such that a function $f = \Sigma c_i\phi_i$ may be regarded as a vector in the space with coordinates c_i.

HILBERT TRANSFORM. **Integral transforms** defined by

$$f(x) = \frac{1}{2\pi}\int_{-\pi}^{\pi}\left[1 + \cot\frac{(x-y)}{2}\right]\phi(y)dy$$

$$\phi(y) = \frac{1}{2\pi}\int_{-\pi}^{\pi}\left[1 + \cot\frac{(x-y)}{2}\right]f(x)dx.$$

HILDEBRAND ELECTRODE. See **electrode, Hildebrand.**

HILDEBRAND RULE. The **entropy** of vaporization, i.e., the ratio of the heat of vaporization to the temperature at which it occurs, is a constant for many substances if it is determined at the same **molal concentration** of vapor for each substance.

HILL AND DALE RECORDING. See **vertical recording.**

HILL DETERMINANT. A **determinant** of infinite order which occurs for **differential equations** with **periodic coefficients,** like **Mathieu's equation.** Its solution determines a parameter in the solution of the differential equation and the **eigenvalues** required to give solutions which are also periodic.

HINDRANCE. In switching-circuit terminology, the description of the impedance provided by switch contacts is referred to as hindrance. The two values of hindrance are denoted by **0** (zero ohms) and **1** (infinite ohms).

HIPERCO. Trade name for a magnetic alloy composed of 35% cobalt, 0.5% chromium, and the balance iron, which has high permeability and a high saturation flux-density.

HIPERNIK. Trade name for an isotropic magnetic alloy whose composition is approximately 50% nickel, 50% iron.

HIPERNIK V. Trade name for a magnetic alloy similar to **Hipernik** in chemical composition, but with grain-oriented properties.

HIPERSIL. Trade name for a highly grain-oriented, silicon-iron magnetic alloy.

HITTORF DARK SPACE. See **cathode dark space.**

HITTORF METHOD (FOR TRANSPORT NUMBER). Comparison of the change in concentration of **electrolyte** near the cathode and near the anode, due to the passage of a

known amount of electricity, can yield the **transport numbers** of the anion and cation of the electrolyte. This is the basis of the Hittorf method.

HITTORF PRINCIPLE. An application of the **Paschen law,** which states that discharge between electrodes in gas at a given pressure will not always occur between the closest points of the electrodes if the distance between these points corresponds to a point to the left of the minimum of the **ignition potential curve.** Also known as the **short-path principle.**

HITTORF TUBE. An early form of **cathode-ray tube.**

HODECTRON. A **mercury-vapor tube** in which the discharge is initiated by means of a magnetic pulse.

HODOSCOPE. An arrangement of radiation **counters** used in **cosmic ray** detection.

HOFFMAN ELECTROMETER. See **electrometer, Hoffman.**

HOFMANN METHOD FOR VAPOR PRESSURE. A graduated glass tube about 1 meter long is filled with mercury and inserted in a trough of mercury, the upper part of the tube being surrounded by a constant-temperature jacket through which is circulated at a known temperature the vapor whose density is required. A small, stoppered, glass vessel containing a known weight of the liquid is inserted into the tube containing mercury, and the liquid vaporizes, forcing off the stopper. The mercury level is depressed, the depression giving the volume of vapor at the pressure and temperature of the experiment. Hence the vapor density is found.

HOFMEISTER SERIES. A definite order of arrangement of **anions** and **cations** according to their powers of coagulation when their salts are added in quantity to lyophilic sols. Thus, the order of cations is $Mg^{++} > Ca^{++} > Sr^{++} > Ba^{++} > Li^{+} > Na^{+} > K^{+} > Rb^{+} > Cs^{+}$. The Hofmeister series is also called the **lyotropic series,** and the effect is called salting-out, a term applied strictly to the effect of electrolytes upon true solutions.

HOHLRAUM. A name for a **black body,** since the only physically-possible black body is a uniform temperature cavity.

HOLBURN AND HENNING METHOD FOR SPECIFIC HEAT AT CONSTANT PRESSURE. An improved method similar to that used by Regnault, by which the specific heat of gases can be determined up to 1400°C.

HOLD-BACK AGENT. The inactive isotope or isotopes of a radioactive element(s) or an element of similar properties or some reagent which may be used to diminish (hold-back) the amount of the radionuclide coprecipitated or adsorbed on a particular carrier or adsorbent. The hold-back agent, because of its relatively high concentration compared to the radionuclide, is presumed to play the major role in saturating the "active" spots on the carrier or adsorber, thus reducing the amount of the radionuclide carried or adsorbed.

HOLD CONTROL. In television, the variable resistor that permits adjustment of the **synchronizing oscillator** until the latter frequency nearly equals that of the incoming **synchronizing pulses.** Colloquialism for **synchronization controls.**

HOLDING ANODE. See **anode, holding.**

HOLDING BEAM. See **beam, holding.**

"HOLE." In general, a **state** or **energy level** not occupied by a particle, particularly when adjacent levels are filled. The term is applied particularly to the case of electrons in a metal, or **semiconductor,** where it is more convenient to describe an **energy band** as containing just a few holes, rather than as nearly full of electrons. This usage is reinforced by the circumstance that the electrons in such states, near the top of a band, have anomalous properties, such as negative **effective mass,** whereas the holes, representing the absence of such anomalous electrons, are mobile, and behave otherwise as if they were normal particles (although, of course, of opposite electric charge). The same idea is at the heart of Dirac's theory of the **positron,** and is useful in the theory of **nuclear shell structure,** of atomic energy levels, etc.

HOLE CURRENT. An electric current in a **semiconductor** in which the carriers appear to have positive charges, and are hence to be associated with **holes** in the electron distribution.

HOLE DENSITY. The density of **holes** in an otherwise full **band, as in a semiconductor.**

HOLE-ELECTRON PAIR. See **exciton.**

HOLE INJECTION. A sharp metallic point applied to the surface of an n-type semiconductor (see **semiconductor, n-type**) can emit **holes** in the bulk of the material, where they are capable of carrying a current. This is the basis of the action of certain types of **transistor.** (See **emitter.**)

HOLE THEORY OF ELECTRODYNAMICS. See **positron theory.**

HOLE THEORY OF LIQUIDS. Liquids differ from solids in having a sufficient number of unoccupied positions, "holes," in the **lattice** that comparatively free movement of molecules is possible by movement into unoccupied sites. The volume of the holes is the **free volume.**

HOLLOW-CATHODE TUBE. Discharge tubes with an atmosphere of inert gas have been designed in which radiation is emitted almost exclusively from the cathode glow inside a hollow electrode closed at one end. Spark lines of the metal comprising the cathode occur in the spectrum.

HOLOHEDRAL CRYSTAL. A **crystal** in which the full number of faces are developed, corresponding to the maximum and complete **symmetry** of the system.

HOLOMORPHIC. See **analytic.**

HOMOCENTRIC RAYS. Rays having the same **focal point.** (It may be at infinity; in other words, the rays may be parallel.)

HOMODYNE. See **detector, homodyne.**

HOMOGENEOUS. (1) A substance is said to be homogeneous if it has the same basic properties at every point, i.e., if its properties are independent of position. (2) In mathematics, a term used with several different meanings. (See **function, homogeneous; equation, homogeneous; differential equation, homogeneous; integral equation; boundary conditions, homogeneous.**)

HOMOGENEOUS MULTIPLYING SYSTEM. A nuclear **reactor** in which the fuel is homogeneously distributed throughout the **moderator,** as, for example, a uranium salt dissolved in water.

HOMOMETRIC PAIRS. Two **crystal structures** having the same **X-ray diffraction pattern.** This is possible because, basically, a diffraction pattern depends only on the relative vector distances between the atoms in the lattice, not on their absolute positions in space.

HOMOPOLAR BOND. A covalent bond (see **bond, covalent**) which has no resultant **dipole moment.**

HOOK-COLLECTOR TRANSISTOR. See **transistor, hook-collector.**

HOOK, P-N. A current-multiplying **collector region** formed by the insertion of an additional junction between the base and collector terminals of a junction transistor. (See **transistor, junction.**) The "hook"-shaped, potential gradient diagram resulting from this configuration permits carrier multiplication and resultant high values of α or **current gain** (in excess of unity).

HOOKE LAW. The law relating small deformations of elastic bodies to the applied stress. The elongation, compression, or shear, called the **strain,** is proportional to the **stress** (force per unit area) within the **elastic** limit. (See **stress.**)

HOOPES CONDUCTIVITY BRIDGE. See **bridge, Hoopes conductivity.**

HOP. The path taken by a radio wave which reaches the point of reception after one or more reflections from the **ionosphere.**

HORIZONTAL BLANKING. The interruption of the electron beam of a **cathode-ray tube** during **horizontal retrace.**

HORIZONTAL CENTERING CONTROL. A control that enables the operator to move a **cathode-ray** image in a right or left direction across the screen.

HORIZONTAL DEFLECTING ELECTRODES. The pair of electrodes located in the vertical plane in an electrostatic-deflection **cathode-ray tube** which are used to produce beam deflection in the horizontal plane.

HORIZONTAL FLYBACK. See **horizontal retrace.**

HORIZONTAL HOLD CONTROL. The control which varies the **free-running period**

of the horizontal-deflection oscillator in a television receiver.

HORIZONTAL LINE FREQUENCY. In television, the number of horizontal lines per second: 15,750.

HORIZONTAL RESOLUTION. In television, the number of light variations or picture elements along a line, which can be distinguished from each other

HORIZONTAL RETRACE. In cathode-ray equipment with linear, horizontal time-base, the rapid right-to-left motion of the electron beam at the end of each sweep.

HORIZONTAL SWEEP. Sweep of an electron beam in the horizontal plane.

HORN, ACOUSTIC. A tube of varying cross section having different terminal areas which provide a change of acoustic impedance (see **impedance, acoustic**) and control of the **directivity pattern.**

HORN, BICONICAL. An electromagnetic horn, consisting of two cones with their vertices coinciding or adjacent. This horn gives a uniform pattern in a plane perpendicular to the axis and highly directional in any plane containing the axis

HORN, COMPOUND. (1) A **loudspeaker system** consisting of a single diaphragm mechanism with one side of the diaphragm coupled to a straight-axis horn and the other side coupled to a long, folded horn. (2) An electromagnetic horn (see **horn, electromagnetic**) of rectangular cross section, the four sides of which diverge in such a way as to coincide with, or to approach four planes, with the provision that the line of intersection of two opposite planes does not intersect the line of intersection of the remaining planes. The electromagnetic field in such a horn is not simply expressed in terms of a family of cylindrical coordinates or a family of spherical coordinates.

HORN, CONICAL. A horn whose cross-sectional area increases as the square of the axial length.

HORN, ELECTROMAGNETIC. Horn radiators are used to obtain directional radiation characteristics which could not be obtained as conveniently with simple antennae. As such directors they are used both with conventional antennae and with wave guides, but in either case they serve to direct the radiation in a pattern from the open end of the horn in a manner determined by the dimensions of the horn. The important dimensions are the horn opening (in terms of wavelength of the radiation) and the flare angle. While theoretically an infinitely long horn will give a radiation pattern whose angle conforms to that of the horn, those of practical length do not confine the beam to quite this degree. For example a horn with an angle of 15° may give a radiation pattern which spreads 23°. For types of electromagnetic horns, see **horn, biconical; horn, pyramidal; horn, sectoral,** etc.

HORN EQUATION, FUNDAMENTAL. The equation for the velocity potential ϕ at a point x along a horn is given by

$$\frac{\partial^2\phi}{\partial t^2} - c^2 \frac{\partial\phi}{\partial x}\frac{\partial}{\partial x}(\ln S) - c^2 \frac{\partial^2\phi}{\partial x^2} = 0,$$

where S = cross-sectional area of horn at x, c = velocity of sound.

HORN, EXPONENTIAL. A horn whose cross-sectional area increases exponentially with axial distance. If S is the area of a plane section normal to the axis of the horn at a distance from the throat of the horn, and S_0 is the area of the plane section normal to the axis of the horn at the throat, and m is a constant which determines the rate of taper of flare of the horn, then

$$S = S_0 \epsilon^{mx}.$$

(See also **horn, finite exponential.**)

HORN, FINITE CONICAL. A horn consisting of a truncated right circular cone of finite length The acoustical impedance at the throat of such a horn, Z_{A1}, is expressed by

$$Z_{A1} = \frac{\rho c}{S_1}\left[\frac{\left\{ iZ_{A2}\dfrac{\sin k(l-\theta_2)}{\sin k\theta_2} + \dfrac{\rho c}{S_2}\sin kl \right\}}{\left\{ Z_{A2}\dfrac{\sin k(l+\theta_1+\theta_2)}{\sin k\theta_1 \sin k\theta_2} - \dfrac{i\rho c}{S_2}\dfrac{\sin k(l+\theta_1)}{\sin k\theta_1} \right\}}\right]$$

where S_1 is the area of the throat in cm^2, S_2 is the area of the mouth in cm^2, l is the length of horn in cm, $k\theta_1$ is $\tan^{-1}(kx_1)$, $k\theta_2$ is $\tan^{-1}(kx_2)$, x_1 is the distance from apex to throat in cm, x_2 is the distance from apex to mouth in cm, k is $2\pi/\lambda$, λ = wavelength in cm, c is the velocity of sound in cm/sec, ρ is the density of air in gm/cm^3, and Z_{12} is the acoustic impedance at the mouth of the horn in acoustical ohms.

HORN, FINITE CYLINDRICAL. A horn consisting of a right circular cylinder of finite length. The acoustic impedance at the throat of such a horn, Z_{11}, is given by

$$Z_{A1} = \frac{\rho c}{S_1}\left(\frac{S_1 Z_{12} \cos kl + i\rho c \sin kl}{iS_1 Z_{12} \sin kl + \rho c \cos kl}\right),$$

where ρ is the density of air in gm/cm^3, k is $2\pi/\lambda$, λ is the wavelength in cm, c is the velocity of sound in cm/sec, S_1 is the cross-sectional area of cylinder in cm^2, l is the length of horn in cm, and Z_{12} is the acoustic impedance at the mouth of the horn, in acoustical ohms.

HORN, FINITE EXPONENTIAL. A horn with a circular cross-section, the area of which is given by $S = S_1 e^{mx}$, where S_1 is the area at the throat and x is the distance measured along the axis of the horn. The acoustic impedance at the throat of such a horn, Z_{11}, is given by

$$Z_{11} = \frac{\rho c}{S_1}\left[\frac{S_2 Z_{A2}\{\cos(bl + \theta) + i\rho c \sin bl\}}{iS_2 Z_{A2} \sin bl + \rho c \cos(bl - \theta)}\right],$$

where S_1 is the area of throat in cm^2, S_2 is the area of mouth in cm^2, l is the length of horn in cm, Z_{12} is the acoustic impedance at the mouth, in acoustical ohms, θ is $\tan^{-1} a/b$, a is $m/2$, b is $(\frac{1}{2})\sqrt{4k^2 - m^2}$, k is $2\pi/\lambda$, λ is the wavelength in cm, ρ is the density of air in gm/cm^3, and c is the velocity of sound in cm/sec.

HORN, FOLDED. A horn in which the path from throat to mouth is folded or curled, so that a larger path length is obtained for a given volume.

HORN, INFINITE CONICAL. A horn consisting of a truncated right circular cone of infinite length. The acoustic impedance Z_A at the throat of such a horn is given by

$$Z_A = \frac{\rho c}{S_1}\frac{ikx_1}{1 + kx_1}$$

where x_1 is the distance of the throat from apex in cm, S_1 is the area of throat in cm^2, k is $2\pi/\lambda$, λ is the wavelength in cm, ρ is the density of air in gm/cm^3, and c is the velocity of sound in cm/sec.

HORN, INFINITE CYLINDRICAL. A horn consisting of a right circular cylinder which extends to infinity in one direction. The acoustic impedance of such a horn, Z_A, is given by

$$Z_A = \frac{\rho c}{S_1}$$

where ρ is the density of air in gm/cm^3, c is the velocity of sound in cm/sec, and S_1 is the cross-sectional area of horn in cm^2.

HORN, INFINITE EXPONENTIAL. A horn with a circular cross-section and infinite length (i.e., of length >> λ) whose area is given by $S = S_1 e^{mx}$, where S_1 is the area at throat, in cm^2, x is the distance measured along the axis of the horn in cm. The acoustic impedance at the throat of such a horn, Z_A, is given by

$$Z_A = \frac{2ik\rho c}{S_1[m + i\sqrt{4k^2 - m^2}]},$$

where ρ = density of air in gm/cm^3, k is $2\pi/\lambda$, λ is the wavelength in cm, and c is the velocity of sound in cm/sec.

HORN, INFINITE HYPERBOLIC. A horn whose cross-sectional area along the axis is expressed by

$$S = S_1(\cosh\alpha + T\sinh\alpha)^2,$$

where T is the family parameter; in the hyperbolic horn, $T < 1$, α is x/x_0, the dimensionless axial distance, x is the axial distance from throat in cm, x_0 is the reference axial distance in cm, and S_1 is the area at throat in cm.

The acoustic impedance at the throat of such a horn, Z_A, is given by

$$Z_A = \frac{\rho c}{S_1}\left[\sqrt{1 - \frac{1}{\mu^2}} + \frac{iT}{\mu}\right]\left[1 - \frac{1 - T^2}{\mu^2}\right]^{-1},$$

where μ is kx_0, k being $2\pi/\lambda$ and λ, the wavelength in cm.

HORN, INFINITE PARABOLIC. A horn whose cross-section area S is given by $S = S_1 x/x_1$, where S_1 is the area in cm^2 at

the throat ($x = x_1$). The acoustic impedance at the mouth of such a horn, Z_A, is given by

$$Z_A = \frac{i\rho c}{S_1} \frac{J_0(kx) - iY_0(kx)}{J'_0(kx) - iY'_0(kx)},$$

where J_0 is the Bessel function of the first kind of order zero, Y_0 is the Bessel function of the second kind of order zero, J'_0, Y'_0 are derivatives of J_0, Y_0, respectively, ρ is the density of air in gm/cm^3, c is the velocity of sound in cm/sec, k is $2\pi/\lambda$, and λ is the wavelength in cm.

HORN, HYPEX. See **hypex horn.**

HORN LOUDSPEAKER. See **loudspeaker, horn.**

HORN MOUTH. Normally the end of an acoustic horn with the larger cross-sectional area.

HORN, MULTICELLULAR. A cluster of horns with juxtaposed mouths which lie in a common surface. The purpose of the cluster is to control the **directional pattern** of the radiated energy.

HORN, MULTIPLE CHANNEL, MULTIPLE-. A **loudspeaker system** consisting of a low-frequency folded horn unit and a multicellular horn unit for the reproduction of the higher frequencies.

HORN, PYRAMIDAL. An electromagnetic horn (see **horn, electromagnetic**), the sides of which form a pyramid. The electromagnetic field in such a horn would be expressed basically in a family of spherical coordinates.

HORN RADIATOR. A radiating element having the shape of a horn.

HORN, SECTORAL. An electromagnetic horn, two opposite sides of which are parallel, and the two remaining sides of which diverge. The electromagnetic field in such a horn would be expressed basically in a family of cylindrical coordinates.

HORN, SINGLE CHANNEL, MULTIPLE-. A **loudspeaker system** consisting of a large number of multiple flare horns, each driven by a diaphragm.

HORN, SINGLE CHANNEL, SINGLE-. A **loudspeaker system** consisting of a single horn driven by a single diaphragm.

HORN SOURCE, CONICAL. A sound source consisting of a plane circular surface source (see **source, plane circular surface**) vibrating at the throat of a finite conical horn.

HORN SOURCE, EXPONENTIAL. A sound source consisting of a plane circular surface source (see **source, plane circular surface**) vibrating at the throat of a finite exponential horn.

HORN SOURCE, PARABOLIC. A sound source consisting of a plane sound source (see **source, plane**) (either circular or rectangular) vibrating at the throat of a finite parabolic horn (of either circular or rectangular cross-section).

HORN THROAT. Normally the end of an acoustic horn with the smaller cross-sectional area.

HORNER METHOD. A method of successive approximations for finding the approximate value of an irrational root of a **polynomial equation.** Locate the root between successive integers; the smaller integer is the integral part of the root. Now transform the given equation $P(x) = 0$ into another equation $P_1(x) = 0$, whose roots are those of $P(x) = 0$ diminished by the integral part of the root, so that $P_1(x) = 0$ has a root between 0 and 1. Locate the root between successive tenths; the smaller tenth is the tenths part of the root. Continue this process as long as desired, transforming each time to a new equation $P_i(x) = 0$ and finding the location of the roots as before. **Synthetic division** should be used for the various transformations.

HOROPTER. The locus of those points in the field of **binocular vision** which are seen single; the images of which fall on the corresponding retinal points.

HORSE LATITUDE. The regions of calms in the subtropical anticyclone belts.

HORSEPOWER. (1) Historically, the rate at which a horse can do work. (2) Defined by James Watt as 33,000 ft lbf/min, equivalent to 746 **watts.**

HORSEPOWER, FRENCH OR METRIC. A unit of power defined as the power required to raise 75 kilograms through one meter in one second.

"HOT." A colloquial term meaning highly radioactive.

HOT CATHODE (THERMIONIC CATHODE). See **cathode, hot (thermionic cathode).**

HOT-CATHODE TUBE. See **tube, hot-cathode.**

HOT-WIRE METHOD FOR HEAT TRANSMISSION OF GASES. A method for determining the thermal conductivity of a gas, consisting in the measurement of the temperature difference between a heated wire and a cylinder placed coaxially with it, the space between containing the gas. Corrections are necessary for end-effects, for the **accommodation coefficient** at the wire and for convection and radiation. Convection effects become very small below a pressure of about 15 cm of mercury.

HOT-WIRE MICROPHONE. See **microphone, hot-wire.**

HOUR. One twenty-fourth part of a mean solar day, 3600 seconds.

HOWL. Acoustic output of a receiver or sound system due to an undesirable electrical or acoustic **feedback** at some point in the system

HUBBLE CONSTANT. The reciprocal of T in the equation $d = vT$, where v is the velocity of recession of a galaxy which is at a distance d. $T = 5 \times 10^9$ years is sometimes called the age of the universe, although there is no evidence that the name should be taken literally.

HUBBLE LAW. See discussion of **red shift.**

HÜBNER RHOMB. A rhombic glass **prism** used for comparison of two illuminated surfaces in photometry.

HUE. The attribute of color perception that determines whether it is red, yellow, green, blue, purple, or the like. This is a subjective term corresponding to the psychophysical term **dominant** (or **complementary**) wavelength. White, black, and gray are not considered as being hues.

HUE CONTROL. See **phase control.**

HUM. This is the annoying 60- or 120-cycle tone, or some harmonic thereof, sometimes heard in the output of communication equipment. It may be introduced in the circuit in a number of ways, inductive or capacitive coupling with adjacent circuits carrying 60-cycle current, by the use of a-c for heating the **filaments** of vacuum **tubes** or by induced effects from the **heaters** of indirectly heated tubes, by improper filtering of the output of the **rectifiers** supplying the d-c voltages for the operation of the system, etc.

HUM MODULATION. See **modulation, hum.**

HUME-ROTHERY RULES. When **alloy systems** form distinct **phases**, it is found that the ratio of the number of **valence electrons** to the number of atoms is characteristic of the phase (e.g., β-, γ-, ϵ-) whatever the actual elements making up the alloy. Thus, both $Na_{31}Pb_8$ and Ni_5Zn_{21} are γ-structures, with the electron-atom ratio 21:13. The rules are explained by the tendency to form a structure in which all the **Brillouin zones** are nearly full, or else entirely empty.

HUMIDIFICATION. A process for increasing the water content of air or other gases.

HUMIDITY, ABSOLUTE. The mass of water vapor in a specified volume. It can be expressed in any convenient units: ounces per cu yd; grams per cu meter. Example: 22 grams per cu meter.

HUMIDITY, RELATIVE. The fraction or percentage of the actual vapor pressure of the water vapor contained in the atmosphere at a given temperature, to the maximum or saturated vapor pressure of water vapor at the same temperature.

HUMPHRIES EQUATION. An expression for the ratio of **specific heats** of moist air, of use in the calculation of the velocity of sound in the atmosphere:

$$C_p/C_v = \gamma = 1.40 - 0.1e/p,$$

where γ is the ratio of specific heats, p is the total atmospheric pressure, e is the water vapor pressure.

HUND RULES (FOR DETERMINING NORMAL TERM). For electronic configurations containing equivalent p- or d- electrons. Hund suggested the following rules:

(1) The normal term is that with highest value of the **multiplicity.** (2) For atoms in

which the **valence shell** contains less than half the maximum number of electrons the deepest component of a multiplet is that for which $J = L - S$, that is, J has the lowest possible value. Such multiplets are known as regular. (3) When the shell is more than half-filled, the component of the multiplet which has lowest energy is that for which $J = L + S$, that is, J has the highest value. Such multiplets are designated as inverted.

HUNTING. A condition of instability, as for example in a mechanical system or an automatic-control system, which is essentially an uncontrolled oscillation due to excessive **feedback** or **underdamping.** The oscillator swings about a predetermined reference point without seeming to approach it.

HURRICANE. Over all oceans, near the equator, with the exception of the South Atlantic, there develop occasionally tropical **cyclones** which are intense vortices covering relatively large areas. All are the same type of storm. Surface pressure in a hurricane is very low at the center or **eye of the storm** but rises rapidly outward toward the periphery. Because of the large **pressure gradient,** winds are of high velocity, blowing counterclockwise in the northern hemisphere and clockwise south of the equator.

HURTER AND DRIFFIELD CURVE. See **H and D curve; exposure-density relationship;** see also **gamma.**

HUYGENS EYEPIECE. See **eyepiece, Huygens.**

HUYGENS PRINCIPLE. A well-known method of analysis applied to problems of **wave propagation.** It recognizes that each point of an advancing **wave front** is in fact the center of a fresh disturbance, and the source of a new train of waves, and that the advancing wave as a whole may be regarded as the resultant of the secondary waves arising from points in the medium already traversed. This view of wave propagation facilitates the study of various phenomena, such as **diffraction.**

HUYGENS REVERSE WAVE. It has been objected that **Huygens principle** would also result in a disturbance traveling backward. It can be shown that the **amplitude** of the reverse wave at any given point is half the amplitude which would be produced by the first wave alone. Since the **inclination factor** for the wave traveling in the backward direction from the first zone is zero, the whole amplitude of the reverse wave is zero.

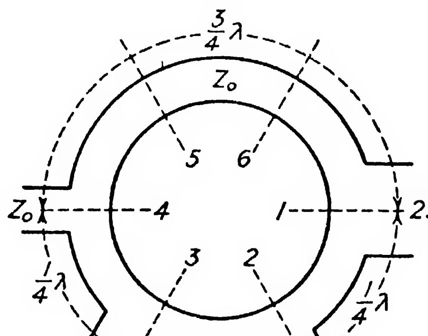
HYBRID COIL. The bridging **transformer** used in coupling a two-way telephone circuit to the repeater station or for coupling two one-way circuits to a two-way circuit. The coil is so wound that when the line is properly balanced by a balancing network there is no reaction between the output and input connections of the transformer

HYBRID ELECTROMAGNETIC WAVE (HEM WAVE). See **wave, hybrid electromagnetic.**

HYBRID JUNCTION. See **junction, hybrid.**

HYBRID RING (RAT-RACE). A hybrid junction which consists of a re-entrant line of proper electrical length to sustain standing waves, to which four side-branches are connected in proper intervals by means of series or parallel **junctions.** In the practical form of this device, a **waveguide** is used for the line.

A cross-sectional view, taken through a plane parallel to the electric field, of a series-connected ring is shown below. When power enters the ring through arm 1, waves of equal amplitude, but opposite phase, leave the junc-



tion and move around the ring in opposite directions. They meet at junction 4, which is diametrically opposite, and produce a voltage **node** at that point. Other voltage nodes appear at points 2 and 6, whereas voltage **antinodes** appear at points 1, 3, and 5. Since power flows into a branch line, connected through a series junction, to a point on the

main line at which there is a voltage node, power is delivered to the side arms at 2 and 4. If the side arms are terminated in their **characteristic impedance,** equal amounts of power are withdrawn through arms 2 and 4. Waves moving past 2 towards 3 and past 4 toward 3 therefore are attenuated equally and, since junctions 2 and 4 are identical, the waves experience equal phase-shifts. The two waves therefore arrive at point 3 with equal amplitudes and phase, and still produce a voltage antinode. Because no power is delivered to a side-arm connected through a series junction at a voltage antinode (current node) no power is delivered to the side-arm at 3.

If the power enters the ring through arm 2 and the remaining arms are terminated in their characteristic impedances, voltage minima appear at points 1 and 3 and a voltage maximum at point 4. Equal amounts of power are then delivered to arms 1 and 3, and no power to arm 4.

HYBRID TEE. A hybrid junction (see **junction, hybrid**) composed of an **E-H tee** with internal matching elements, which is reflectionless for a wave propagating into the junction from any arm when the other three arms are match terminated.

HYBRIDIZATION OF EIGENFUNCTIONS. Strictly speaking, this term means any linear combination of the **eigenfunctions** of one problem used to represent an eigenfunction of another problem. It is applied to problems of electronic **bonding**, where the true **bonding orbitals** may be hybrids of, for example, both *s* and *p* type **atomic orbitals.**

HYDRATED ION. An **ion** which is in combination with one or more water molecules, as $H^+(H_2O)$, or H_3O^+.

HYDRAULIC RADIUS. The ratio of the cross-sectional area of flow to the wetted perimeter of a pipe or channel. By using the hydraulic radius, flow in pipes and channels of different sections may be conveniently correlated. The success of the method implies that the shear stress on the walls is nearly constant. This constancy is due to the presence of a secondary flow in non-circular channels, whose origin is not well understood.

HYDRAULICS. The science of the dynamics and statics of liquids, particularly water, in connection with engineering problems.

HYDRODYNAMICS. The study of the dynamics of fluid motion, especially the steady motions of an incompressible, inviscid fluid.

HYDROGEN. Gaseous element. Symbol H Atomic number 1.

HYDROGEN ELECTRODE. See **electrode, hydrogen.**

HYDROGEN, ISOTOPES. Three isotopes of hydrogen are known: protium which has a mass of 1.00756 (on the chemical atomic weight scale) is by far the most abundant isotope and is denoted by the symbol p or H^1; deuterium which has a mass of 2.0136 (on the chemical atomic weight scale) and is denoted by the symbol d, D or H^2; and tritium which has a mass of 3.0221 (on the chemical atomic weight scale) and is denoted by the symbol t, T or H^3. Deuterium is called heavy hydrogen.

HYDROGEN, ORTHO AND PARA. Two forms of hydrogen, which constitute about 75%, and 25%, respectively, of ordinary hydrogen at room temperature, and which differ somewhat in their physical properties, especially in their specific heats. At very low temperature, as for liquid hydrogen, the para form is present to the extent of 99.7%. The difference between the two forms is explained on the assumption that the two nuclei in the H_2 molecule are spinning in anti-parallel directions in the case of para hydrogen and in parallel directions in ortho hydrogen

HYDROGEN SCALE (FOR ELECTRODE POTENTIALS). Since there is no reliable method for determining the absolute potential of a single electrode, **electrode potentials** are measured against a reference electrode whose potential is arbitrarily taken as zero. The arbitrary zero in general use is the potential of a reversible hydrogen electrode, with gas at 1 atmosphere pressure, in a solution of hydrogen ions of unit **activity.**

HYDROMETEORS. Condensation products of atmospheric processes often appear as hydrometeors or bodies of falling liquid and solid water. (See **rain, snow, drizzle, sleet, hail, snow pellets, hail (small).**)

HYDROMETER. An instrument for measuring the density of liquids. Essentially, it is a long slender glass float, weighted at the lower end so that it floats in the vertical posi-

tion and provided with a scale measuring depth of immersion. If the float section at the free surface is constant, the depth of immersion is a linear function of the reciprocal of density.

HYDROPHONE. An electroacoustic transducer (see **transducer, electroacoustic**) which responds to water-borne sound waves and delivers essentially equivalent electric waves. In a manner similar to the use of the adjective "line" in the definition of line hydrophone (see **hydrophone, line**) and line microphone (see **microphone, line**), the adjectives "pressure," "velocity," "gradient," "omnidirectional," "unidirectional," "carbon," "capacitor," "crystal," "magnetic," "magnetostriction," "moving-coil," and "moving-conductor," when applied to a hydrophone, have meanings similar to those that apply in the case of a microphone. (See **sonar.**)

HYDROPHONE, DIRECTIONAL. A **hydrophone** the response of which varies significantly with the direction of the sound incidence.

HYDROPHONE, LINE. A directional hydrophone (see **hydrophone, directional**) consisting of a single straight line element, or an array of contiguous or spaced electroacoustic transducing elements disposed on a straight line, or the acoustic equivalent of such an **array.**

HYDROPHONE, SPLIT. A directional hydrophone (see **hydrophone, directional**) in which electroacoustic transducing elements are so divided and arranged that each division may induce a separate electromotive force between its own electric terminals.

HYDROSTATIC PRESSURE. Strictly, the pressure in a fluid at rest, caused by the weight of the superimposed column of fluid. Considerations of equilibrium show that the pressure transmitted across a small surface in the fluid is independent of the orientation of the surface. Frequently used for the negative of the mean normal stress in a moving fluid, or for the pressure which would satisfy the equation of state of the fluid.

HYDROSTATIC SOUND PRESSURE. See **pressure, static.**

HYDROSTATICS. The study of the static equilibrium of fluids.

HYDROSTATICS, FUNDAMENTAL EQUATIONS OF. If **F** is the vector force per unit mass due to an external **field of force,**

$$\rho \mathbf{F} = \mathbf{grad}\ p$$

where p is the hydrostatic pressure, and ρ is the local fluid density, from considerations of equilibrium. If the external force field is a potential field, both density and pressure must be constant over equipotential surfaces of the force field.

HYGROMETER. An instrument used to measure the absolute or relative water content of air. The most common types are the **psychrometer,** the hair hygrometer (see **hygrometer, hair**), and the dew-point hygrometer (see **hygrometer, dew point**). There are also absorption hygrometers, diffusion hygrometers, optical hygrometers and other types.

HYGROMETER, DEW POINT. An instrument which measures the temperature at the time of formation and evaporation of dew. A mean of the temperature at time of formation and evaporation is approximately the actual dew-point temperature. Some instruments require visual observation of dew drops on the instrument and the disappearance of the same drops, but others use photoelectric cells to determine the time of dew formation and evaporation.

HYGROMETER, HAIR. An instrument in which strands of human hair mounted under tension expand with increasing relative humidity and contract with decreasing relative humidity. One end of a set of strands is fixed and the other end operates a set of levers whose initial movement is magnified mechanically to cause a pointer or other indicating device to ride over a calibrated scale.

HYGROSCOPIC. Becoming wet, or capable of becoming wet, by absorption of water from the atmosphere. Substances exhibiting this behavior at atmospheric temperature and humidity are called hygroscopic substances.

HYMN 88. Commercial name for a high permeability magnetic alloy having 79% nickel, 4% molybdenum and the balance iron.

HYPERBOLA. A **conic section** obtained by a plane cutting both **nappes** of a right circular **conical surface.** It is the locus of a

point which moves so that the difference of its distances from two foci is a constant. Its **eccentricity** is greater than unity.

The standard equation may be taken as

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1.$$

The curve is a **central conic** for it is symmetric about both the X- and Y-axes when placed in this standard position and the coordinate origin is its center. The transverse **axis,** coincident with the X-axis, is of length $2a$; the conjugate axis, along the Y-axis, has length $2b$ $(b < a)$. The distance from the center of the hyperbola to either focus is $\sqrt{a^2 + b^2}$; the eccentricity, $e = \sqrt{a^2 + b^2}/a$; the length of the **latus rectum** is $2b^2/a$; the equations for the **directrices** are $x = \pm a/e$, the same as for the ellipse The distance from any point on the hyperbola to a focus is a **focal radius** and the difference between any two focal radii equals $2a$ The lines $y = \pm bx/a$ are **asymptotes** to the hyperbola. If the lengths of the transverse and conjugate axes become equal $(a = b)$, the curve is an equilateral or rectangular hyperbola

HYPERBOLIC FUNCTION. Combinations of $e^{\pm z}$ with properties similar to those of the **trigonometric functions.** They are defined by:

$$\sinh z = \frac{1}{2}(e^z - e^{-z}) = z + \frac{z^3}{3!} + \frac{z^5}{5!} + \cdots;$$

$$\cosh z = \frac{1}{2}(e^z + e^{-z}) = 1 + \frac{z^2}{2!} + \frac{z^4}{4!} + \cdots;$$

$$\tanh z = \frac{\sinh z}{\cosh z};$$

$$\coth z = 1/\tanh z;$$

$$\operatorname{sech} z = 1/\cosh z;$$

$$\operatorname{csch} z = 1/\sinh z.$$

For real z, their geometric representation is related to the **hyperbola** as the trigonometric functions are related to a **circle.** The two sets of functions are connected by the equations

$$\sinh iz = i \sin z;$$

$$\cosh iz = \cos z;$$

$$\tanh iz = i \tan z.$$

HYPERBOLIC LOGARITHM. A logarithm to the base e; a **natural logarithm.**

HYPERBOLIC PARTIAL DIFFERENTIAL EQUATION. A special case of the general **partial differential equation** where $B^2(x,y) > A(x,y)C(x,y)$ for all x,y. The characteristic curves are real and the normal form is

$$\frac{\partial^2\psi}{\partial\lambda\partial\mu} = P(\lambda,\mu)\frac{\partial\psi}{\partial\lambda} + Q(\lambda,\mu)\frac{\partial\psi}{\partial\mu} + R(\lambda,\mu)\psi.$$

Specification of **boundary values** and normal derivatives **(Cauchy conditions)** assure a unique solution unless the boundary coincides with a **characteristic.** When the boundary is closed, the Cauchy conditions overdetermine the solution. The **wave equation** is an example of a hyperbolic equation.

HYPERBOLOID. A **central quadric** with one or two negative terms in its equation. If there is only one, so that

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} - \frac{z^2}{c^2} = 1$$

the surface is a hyperboloid of one sheet, given this name because any point on the surface may be reached from any other point on the surface. A plane parallel to the XY-plane gives an **ellipse** but if the sections are parallel to the XZ- or YZ-planes the results are **hyperbolas.** When $a = b$, the sections by planes z = constant are **circles** and the surfaces can be generated by revolving the hyperbola, $x^2/a^2 - z^2/c^2 = 1$ about its conjugate axis, the Z-axis.

If there are two negative terms in the equation

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} - \frac{z^2}{c^2} = 1$$

the surface is a hyperboloid of two sheets, separated into two parts symmetrically located above and below the planes x = constant. Traces parallel to the XY- and XZ-planes are hyperbolas and traces parallel to the YZ-planes are ellipses, provided $x > a$. When $b = c$, the sections by planes x = const. are circles and a surface of revolution results when the hyperbola $x^2/a^2 - y^2/c^2 = 1$ is rotated about its X- or transverse axis.

HYPERCONJUGATION. The description of the properties of a molecule in terms of **resonance** structures in which an atom or

group is not joined by any sort of bond to the atom to which it is ordinarily considered linked. Also called no-bond resonance.

HYPERFINE STRUCTURE. In general, a set of very closely spaced lines making up a **spectral line,** or **paramagnetic resonance** line. There may be many causes of hyperfine structure, including: (1) For a single atomic species or nuclide, the occurrence of spectral lines as doublets, triplets, etc., due to the interaction, or coupling, of the **total angular momentum** of the orbital electrons with the **nuclear spin** and associated magnetic moment. (2) For an element consisting of several isotopes, the occurrence of components for each spectral line that is observable under high resolution, each isotope contributing one or more components. This type of hyperfine structure is often called isotope structure to differentiate it from the first type of hyperfine structure discussed above.

HYPERGEOMETRIC. Name given to a certain **differential equation** and its solutions, studied by Gauss. (See **Gauss hypergeometric equation** and **Gauss hypergeometric function.**)

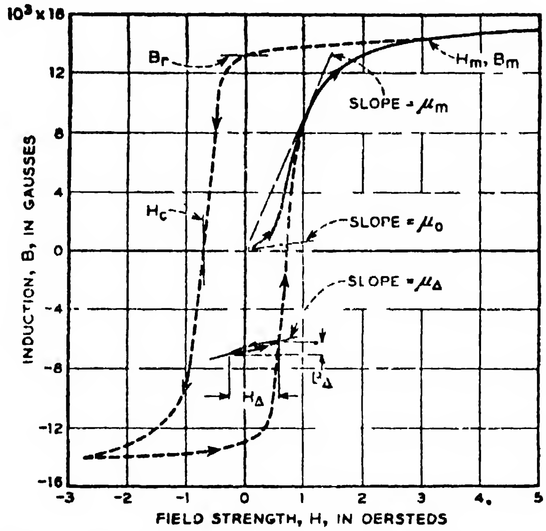
HYPERON. Any particle with mass intermediate between that of the neutron and the deuteron. For behavior of the Λ^+ and Λ^0 hyperons see the classification of particles proposed by the International Cosmic-Ray Congress in 1953, and given in this book under the heading **meson.**

HYPEROPIA (HYPERMETROPIA). A condition of the eye in which parallel rays are focused behind the **retina;** farsighted.

HYPEX HORN. An acoustic horn designed to give accentuated response at low frequencies.

HYSTERESIS. In general, the phenomenon exhibited by a system whose state depends on its previous history. This term usually refers to magnetic hysteresis, of importance in **alternating-current** machinery. When a ferromagnetic material such as iron is placed in a magnetic field, a certain amount of energy is involved in bringing about its magnetization. If the field is a rapidly alternating one, the material may become noticeably warm. It appears that the repeated changes of orientation in whatever it is within the substance that responds to the reversals of field are opposed by something like viscous friction.

A quantitative study of the process indicates that, as the field intensity H increases, the magnetic induction B also increases in a manner characteristic of the substance. This is conveniently represented by a graph, which is called the magnetization curve (see figure). Its initial slope is the initial permeability (μ_0). If H is carried to some maximum value H_m and then reduced (to $-H_m$), B follows the dotted hysteresis curve. B does not fall off as it was built up (solid line); the residual induction B_r is the induction remaining when H has been reduced to zero; the reverse H needed to reduce B to zero is called the coercive force (H_c). From this point the cycle proceeds to describe the closed curve shown by the dotted lines, which is called the hysteresis loop. The initial portion (solid line) is not retraced. The amount of energy converted into heat is proportional to the area of the cycle



Hysteresis loop (dotted). Some important magnetic quantities are illustrated (By permission from "Ferromagnetism" by Bozorth, Copyright 1951, D. Van Nostrand Co., Inc.)

Electric hysteresis is a somewhat analogous phenomenon exhibited by **dielectrics** in the electric field and gives rise to heating in a-c condensers.

Some solids exhibit what is called elastic hysteresis, in which the variables corresponding to H and B in the magnetic case are the stress and the strain or deformation. Elastic bodies such as metals operating at stresses below the **proportional limit** also undergo

hysteresis. If B represents positive or tensile stress and H represents positive strain or elongation, the action of an elastic metal under cyclic or reversed stress can be represented by $OSC'S'CS$. By definition of the proportional limit the line OS should be straight; however, highly sensitive measurements show a slight curvature, leading to the development of a loop of appreciable thickness. The area within the loop is proportional to the loss of energy in a complete cycle of reversed stress. (See also **magnetization curve.**)

HYSTERESIS DISTORTION. The distortion of voltage and/or current **waveforms** in circuits containing magnetic components, which is caused by the non-linear **hysteresis** effect.

HYSTERESIS ENERGY. The energy used per cycle of operation to overcome the effect of **hysteresis.**

HYSTERESIS HEATER. An induction device in which a charge or a muffle about the charge is heated principally by **hysteresis losses** due to a **magnetic flux** which is produced in it. A distinction should be made between hysteresis heating and the enhanced induction heating in a magnetic charge.

HYSTERESIS HEATING. The temperature rise caused by the expenditure of **hysteresis energy.**

HYSTERESIS LOOP. See **hysteresis** and **magnetization curve.**

HYSTERESIS LOOP, DYNAMIC (A-C HYSTERESIS LOOP, FLUX-CURRENT LOOP, FLUX-AMPERE-TURN LOOP). Of a **core,** the curve of magnetization versus applied magnetomotive force per unit length obtained when the magnetic material is cyclically magnetized at some specified rate. The magnetization at any instant is the average flux density over the entire core section. The applied magnetomotive force per unit length at any instant is that required to provide the flux and rate-of-change of flux implicit in the test or operating specifications.

HYSTERESIS LOSS. Since the change of **magnetic energy** accompanying a change of **magnetization** is $dE = HdB$ per unit volume, a cyclic change requires the total expenditure of

$$E = \oint dE = \oint HdB$$

$$= \text{area inside the } BH \text{ curve followed.}$$

This energy is converted to heat and is called "hysteresis loss."

HYSTERESIS, ROTATIONAL. If a disc of magnetic material is placed in a **magnetic field** parallel to a diameter, and rotated slowly about an axis perpendicular to the disc, the hysteresis of the material makes the magnetization non-parallel to the applied field. This results in a resisting torque, L, and therefore net energy loss per rotation of

$$\int_0^{2\pi} L d\theta.$$

I

I. (1) Areal moment of inertia (I). (2) Moment of photographic plate (i). (3) Van't Hoff factor (i). (4) Ionic strength (I). (5) Vapor pressure constant (i). (6) Nuclear mechanical magnetic moment, or spin quantum number (I). (7) Radioactivity, initial (I_0), at time t (I). (8) Candlepower or luminous intensity (I). (9) Integration constant for free energy (Gibbs) equation (I). (10) Total electron emission (saturation) (I_s). (11) Conduction current (I). (12) Average current (I_{av}, I). (13) Convection current (I). (14) Effective rms current (I). (15) Instantaneous current (i or I). (16) Maximum current (I_{max} or I_m). (17) Peak current (I_p, I, I_{pk}). (18) Saturation current (I_s). (19) Imaginary unit, $\sqrt{-1}$ (i). (20) Unit vector in X-direction (**i**). (21) Acoustic intensity (I). (22) Angle of incidence (i). (23) Isotopic fine structure (i).

IC. An abbreviation used to indicate an internal connection.

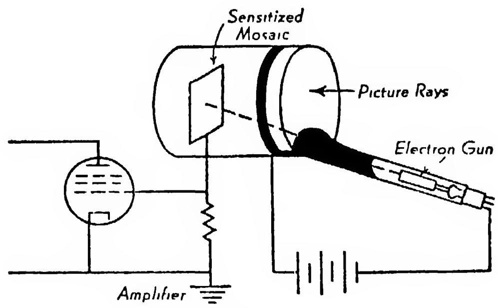
ICE CRYSTAL CLOUDS. At temperatures below about 15°F water vapor changes to solid water directly without the intermediate liquid-water stage. Cloud particles form directly on sublimation nuclei as ice crystals, and such clouds are then composed of ice-crystal particles. Cirro-form clouds are of the ice-crystal group.

ICELAND SPAR. See **calcite.**

ICI. Superseded by **"CIE."**

I_{co}. Symbol for the **collector current** of a **transistor** measured with the **emitter** open-circuited.

ICONOSCOPE. A camera tube (see **tube, camera**) in which a high-velocity electron beam scans a photoactive mosaic which has electrical storage capability. This form of tube is used in television. The scene to be transmitted is focused on the mosaic consisting of very many minute photoelectric cells. They may be formed by various processes, such as treating a sheet of mica with silver oxide, and reducing the oxide to silver in such a way as to form many little globules of silver, which are then photosensitized by treatment with cesium or similar metal. The scene falling upon this mosaic causes the photosensitive particles to emit electrons proportional to the light falling upon them. In the process the particles of silver are charged, to be periodically discharged by the scanning beam of electrons which is swept back and forth across the picture until every particle has been touched in sequence. This electron beam restores the negative charge which the photoelectric action had removed. This sudden restoration of charge gives a pulse of current in the circuit connected to the other plate of the little condenser, i.e., the backing conductor. This pulse magnitude depends upon



Iconoscope

how many electrons had to be restored and hence upon the brilliance of the picture at that point. Since the charges are restored in sequence there will be a sequence of pulses in the output circuit which represents the orderly dissection of the picture into minute parts for transmission. (See figure.)

ICONOSCOPE, IMAGE. See **image iconoscope.**

ICONOTRON. See **image iconoscope.**

ICW. An abbreviation for "interrupted continuous wave." (A continuous wave that is interrupted at a constant audio-frequency rate.)

IDEAL BUNCHING. The idealized condition in **velocity-modulation** tubes which would produce electron bunches containing electrons all of the same velocity and phase (i e., all would pass a given point simultaneously).

IDEAL GAS. See **gas, ideal.**

IDEAL GAS LAW. An "ideal gas" would, if kept at a constant temperature, behave as respects volume and pressure in strict accord with the **Boyle law.** If now the temperature is also allowed to vary, we must combine the **law of Charles** (or of Gay Lussac) with Boyle's law, yielding the **Boyle-Charles law:**

$$pv = p_0v_0(1 + at), \tag{1}$$

in which p_0v_0 is the value of the pressure-volume product pv when the temperature t is zero, a is the coefficient of expansion of the gas, practically the same for all gases, and in the ideal case equal to the reciprocal of the absolute temperature of the scale zero If the centigrade scale is used, the value of a is approximately 1/273 2 per degree. Substituting this, Eq (1) may be written

$$pv = \frac{p_0v_0}{273\ 2°}(t + 273.2°), \tag{2}$$

which is one expression for the ideal gas law.

The factor $t + 273\ 2°$ will be recognized as the **absolute temperature** T of the gas. And since the ideal gas obeys Boyle's law, the product p_0v_0 is constant however p_0 and v_0 may vary between themselves We may thus denote the coefficient $p_0v_0/273\ 2°$ by a single constant symbol, say R, and the ideal gas equation then takes the usual form

$$pv = RT. \tag{3}$$

The value of R depends, of course, upon the quantity of gas used, since at any pressure p_0 it is proportional to the volume v_0. For 1 gram of air, R equals about 2,868,000 $\frac{\text{g cm}^2}{\text{sec}^2\text{ deg}}$. At the zero of temperature and at any given pressure p_0, the gram molecular weights, or moles, of all pure gases have equal volumes. (This follows from the **Avogadro law.**) Hence if one mole of any pure gas is used, R will always have the same value, in c.g.s. units about $8.314 \times 10^7 \frac{\text{g cm}^2}{\text{sec}^2\text{ deg}}$; which is called the "ideal gas constant." Many physical formulae involve a quantity which may be regarded as the ideal gas constant per molecule, that is, the above molar gas constant divided by the number of molecules in a mol, 6.064×10^{23}, giving $1.3805 \times 10^{-16} \frac{\text{g cm}^2}{\text{sec}^2\text{ deg}}$. This is the **Boltzmann constant.**

Since actual gases, even those with the simplest molecules, hydrogen and helium, do not obey the ideal gas law exactly, various empirical **equations of state** or characteristic equations have been devised to represent their behavior.

IDEAL GAS TEMPERATURE SCALE. See **temperature scale, gas.**

IDEAL SOLUTION. See **solution, ideal.**

IDEAL TRANSDUCER. See **transducer, ideal.**

IDEAL TRANSFORMER. See **transformer, ideal.**

IDEMFACTOR. A unit **dyadic** $\mathfrak{I}$, with the properties

$$\mathfrak{I} = \mathbf{a}_1\mathbf{a}_1 + \mathbf{a}_2\mathbf{a}_2 + \mathbf{a}_3\mathbf{a}_3$$

and

$$\mathfrak{I} \cdot \mathbf{V} = \mathbf{V}$$

where $\mathbf{a}_i$ is a **unit vector** and $\mathbf{V}$ is any vector.

IDEMPOTENT. An **operator,** generally a **matrix,** which satisfies the relation

$$\mathbf{A}^2 = \mathbf{A}.$$

The unit matrix is always idempotent, but others can be found, for example

$$\begin{bmatrix} 1 & 0 \\ -1 & 0 \end{bmatrix}.$$

IDENTIFICATION, FRIEND OR FOE. A method of automatic identification of an aircraft or ship A coded, challenging transmission received by a correctly adjusted receiver in a friendly vessel causes the automatic transmission of an identification signal on another frequency Generally known by its initials IFF.

IDENTITY. An **equality** in which both members are equal for all values of the symbols for which the members are defined. Either member can be transformed into the other

by use of the fundamental rules of operation. An identity involves a difference of form but not of value It is frequently indicated by putting the symbol $\equiv$ between the two members. Thus,

$$(a + b)(a - b) \equiv (a^2 - b^2).$$

IDENTITY PERIOD. The distance between identical atomic groupings in the chain molecule of an associated or polymerized substance or in a crystal lattice. The magnitude of this dimension, which is commonly expressed in **Ångström units**, plays an important part in descriptions of structure.

IDIOCHROMATIC. A crystal having **photoelectric** properties characteristic of the material of the pure crystal itself and not due to foreign matter. Also called intrinsic.

IDIOMORPHOUS. Appearing in distinct crystals.

IDIOSTATIC METHOD (OF USE OF QUADRANT ELECTROMETER). See **electrometer, connection of.**

IES. Abbreviation for Illumination Engineering Society.

I-F. Abbreviation for **intermediate frequency.**

IFF. Abbreviation for **identification, friend or foe.**

IGNITER ROD. A high-resistivity, pencil-shaped rod of some material such as **carborundum** which is not wetted by mercury, that is employed to initiate the **arc** in an **ignitron.**

IGNITION NOISE. Interference caused by the ignition systems of internal combustion engines.

IGNITRON. An electron **tube** of the **mercury-arc** type having a special starting principle. The tube consists of a mercury pool, to serve as **cathode,** and an **anode** for the main part of the circuit and an auxiliary electrode, the igniter, which dips into the mercury pool. Since all mercury pool tubes are essentially cold cathode devices until the arc is started some means must be provided for initiating the arc. For rectification of a-c where no provision is made for keeping the arc alive from cycle to cycle or for control purposes where the tube may be alternately turned on and off under the influence of auxiliary equipment, the arc must be restarted at intervals. In the ignitron this is accomplished by the igniter, a rough-surfaced material which will not be "wet" by the mercury. The resultant points of contact between the igniter rod and the mercury will carry very high current densities if a pulse having only a fair current value is passed through it. This high current density, possibly coupled with high fields where the mercury and rod are not actually in contact, cause the creation of a minute cathode spot at the junction of the mercury surface and the rod. This gives the electron emission necessary to start conduction to the main anode if the latter is positive. The current between the spot and the anode then will develop the spot to its normal size. This tube has the advantages of the ordinary mercury-arc tube plus the great advantage of an easily controlled starting mechanism not involving any moving parts It has rapidly come into extensive use for applications requiring ease of control and high current capacities; especially capacities of short-time duration, such as motor control, welding control, rectifiers in electrochemical processes, etc.

ILLUMINANCE (ILLUMINATION). The density of the **luminous flux** on a surface; it is the quotient of the flux by the area of the surface when the latter is uniformly illuminated.

ILLUMINANT, STANDARD. Certain special lamps and filters, which are used as standard sources for colorimetry. For a discussion of standard illuminants, see *The Science of Color*, by the Committee on Colorimetry of the Optical Society of America (1953).

ILLUMINATION. The illumination of a surface is the **luminous flux** which it receives per unit area.

ILLUMINATION, DIRECT. (1) Lighting by visible radiation that passes from light source to object without reflection. (2) In microscopy, light falling directly on the stage of a microscope from above without being reflected by the mirror.

ILLUMINATION, INDIRECT. (1) Lighting by visible radiation that undergoes one or more reflections in its journey from light source to object. (2) In microscopy, light which strikes the object at right angles to the direction of the axis of a microscope.

ILLUMINATION INTENSITY. The **flux density** of light incident upon a surface.

ILLUMINANCE, RETINAL. A psychophysiological quantity, partially correlated with the **brightness** attribute of visual sensation, and measured in **trolands.**

ILLUMINOMETER OR ILLUMINATION PHOTOMETER. An instrument for measuring **illumination.** The older, standard forms of this instrument employ a **photometer** of ordinary type to measure the luminous intensity due to light reflected from a white matt surface or diffused by a white translucent screen exposed to the illumination to be measured. The balance may be secured as usual by the **bench photometer** method, by screening down the comparison lamp, or by turning the diffusing surface through a known angle and relying upon the cosine law (see **illumination**). A different type, known as a foot-candle meter, utilizes the Bunsen screen principle, there being however a long row of translucent spots lighted from behind by a lamp at one end, hence unequally along the row. At some point in the row this balances the illumination from in front, which is to be measured, and a scale indicates the foot-candles directly. In a still more recent instrument the illuminated element is a copper oxide photovoltaic cell (see **photovoltaic effects**) connected to a sensitive current meter reading directly in foot-candles. All of these instruments must, of course, be portable to be of practical use.

ILLUMINOMETER, MACBETH. See **Macbeth illuminometer.**

IMAGE. See **geometrical optics.**

IMAGE ADMITTANCE. Reciprocal of **image impedance.**

IMAGE ANTENNA. See **antenna, image.**

IMAGE ATTENUATION CONSTANT. The real part of the **transfer constant.**

IMAGE CHARGE. See **images, method of.**

IMAGE DISSECTOR. An electron tube serving as a **camera tube** for a television system. The picture to be transmitted is focused on a photosensitive surface, causing electrons to be emitted from each part of the surface in proportion to the amount of light in that particular part of the picture. These electrons are drawn down the tube by a positive anode, but are kept focused in an electron reproduction of the picture. This focusing is done by magnetic fields. The focusing fields or auxiliary fields are varied periodically so the electron picture is swept back and forth, up and down, as it moves down the tube. Placed in the path of this electron picture is an aperture opening into an **electron multiplier.** Each part of the electron stream is thus swept across this aperture and so the output of the electron multiplier will vary with the various parts of the picture. This output, then, represents the electrical unravelling of the picture into an orderly sequence of parts to be transmitted.

IMAGE FREQUENCY. In heterodyne **frequency-converters** in which one of the two sidebands produced by beating is selected, an undesired input frequency capable of producing the selected frequency by the same process. The word "image" implies the mirror-like symmetry of signal and image frequencies about the **beating oscillator frequency** or the **intermediate frequency**, whichever is the higher.

IMAGE ICONOSCOPE. A camera tube which combines the action of a conventional **iconoscope** and an **image dissector** tube. It has about ten times the sensitivity of the iconoscope.

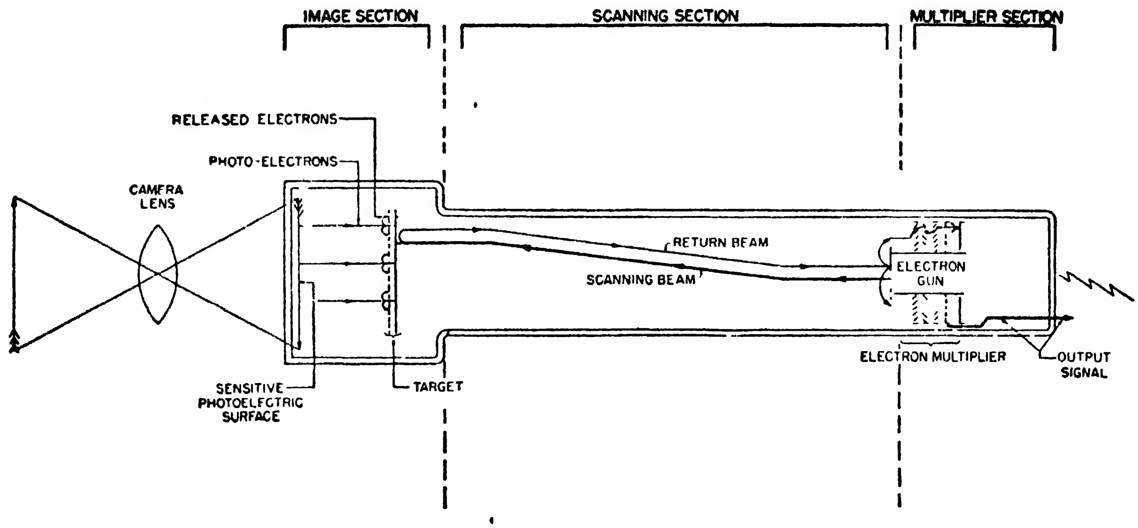
IMAGE IMPEDANCE. That impedance which causes maximum power transfer, as dictated by the **Thevenin theorem,** from the **transducer** to which it is connected.

IMAGE INTERFERENCE. The reception of a station by a superheterodyne receiver at a dial setting differing from the frequency of the station by twice the **intermediate frequency.** This effect is due to the fact that there are two frequencies which may beat with a given oscillator frequency to produce the correct intermediate frequency. Properly designed equipment attenuates one of these signals (it may be either the high or low **frequency** signal) well below audibility. (See **heterodyne** and **receiver.**)

IMAGE - INTERFERENCE RATIO. See **image ratio.**

IMAGE, INVERTED. A real image formed by a single lens or mirror is always inverted, i.e., "upside down" with respect to the object.

IMAGE ORTHICON. A **camera tube** in which an electron image is produced by a



Simplified functional drawing of image orthicon

photoemitting surface, and focused on a separate storage target, which is scanned on its opposite side by a low-velocity **electron beam.**

IMAGE PHASE CONSTANT. The imaginary part of the **transfer constant.** The prefix "image" may be omitted when there is no danger of confusion.

IMAGE RATIO. The ratio of (1) the **field strength** at the **image frequency** to (2) the field strength at the desired frequency, each field being applied in turn, under specified conditions, to produce equal outputs. (See **image interference.**)

IMAGE, REAL. An image formed in such a way that all of the light which passes through an optical system from a point of the object actually passes through a point of the image. If a screen or photographic plate is placed at a real image, a picture of the object will be formed on the screen or plate The image formed on the emulsion by a camera is a typical real image.

IMAGE RECONSTRUCTOR. See **kinescope.**

IMAGE REPRODUCER. See **kinescope.**

IMAGE RESPONSE. The degree of response by a superheterodyne receiver to an **image frequency** signal.

IMAGE TUBE. See **electron image tube.**

IMAGE VERICON. Trade name of a tube similar to the **image orthicon.**

IMAGE, VIRTUAL. In the case that light which passes through an optical system from a point of the object appears to be coming from a new point at which no actual real image is formed, then the system is forming a virtual image of the object. A screen placed at a virtual image will not show a picture of the object. An image seen in a plane mirror is a typical example of a virtual image. This image is as far behind the mirror as the object is in front, yet no light passes through the mirror.

IMAGES, METHOD OF. The potential of a system of isolated, electrical point-charges in an infinite homogeneous medium is

$$V = \frac{q_1}{4\pi\epsilon r_1} + \frac{q_2}{4\pi\epsilon r_2} + \cdots + \frac{q_n}{4\pi\epsilon r_n}$$

where the r's are the distances from a point in space to the corresponding point-charges. Imagine now that an infinitely-thin, perfectly-conducting sheet is introduced over an **equipotential surface.** Since the component of E tangential to an equipotential surface is zero, the boundary condition at the conducting sheet is satisfied by the existing field, which is therefore unaltered. The charges on one side of the sheet are said to be the **images of** the charges on the other side. If all the charges are on the same side of the sheet, they are images of a point-charge at infinity. This relationship may be employed to satisfy the boundary conditions for various field problems. The method of images may be used

for the solution of many non-electrical problems, in which the boundary conditions may be satisfied by the introduction of image sources of flux or energy having effects equal to those produced by reflections from real sources. For example, the acoustic field due to a sound source within a body of water may be found by considering the water to be of infinite depth and by introducing image sources which replace reflections at the upper surface and the bottom of the actual body of water.

IMAGES, POINT. The presence of a **conducting plane** modifies the field of a point charge, q, in the same way as would an image charge, $-q$, located at the mirror-image point behind the plane. Similar theorems may be used to find the effects of other conducting surfaces, such as a sphere or a cylinder, or of **interfaces** between two **dielectrics** having different constants

IMAGINARY NUMBER. See **complex variable.**

IMBIBITION. The penetration of a liquid into a solid system, colloidal or otherwise.

IMPACT. The action of two bodies in collision, whereby the velocity of one or both bodies is changed In the case of direct impact, the velocity of the moving bodies is in the direction of the normal (perpendicular) to the bodies at the point of contact. Otherwise the impact is oblique. The impact is central when the centers of gravity of the two bodies lie on the line of impact (normal to the bodies at the point of contact). The momentum of a body is its mass multiplied by its velocity. A law of impact is that the sum of the momenta of the two masses before and after impact is the same.

IMPACT, ELASTIC. A collision between two objects which, though deformed in the collision, immediately regain their original size and shape. Such an impact is characterized by a **coefficient of restitution** equal to 1. The kinetic energy associated with the direct motion of the objects is conserved in such an impact.

IMPACT EXCITATION. See **shock excitation.**

IMPACT-EXCITED TRANSMITTER. Essentially some form of **spark transmitter.**

IMPACT FLUORESCENCE. Fluorescence of a material due to bombardment of the material by high energy molecules of some other material.

IMPACT, INELASTIC. See **impact, plastic.**

IMPACT PARAMETER. A term used in elastic scattering (see **collision, elastic**) to denote the perpendicular distance from the initial position of the scattering center to the original line of motion of the scattering particle. The use of the term has been extended to apply to any nuclear reaction (see **reaction, nuclear**), where it is the perpendicular distance from the target nucleus to the original line of motion of the incident particle.

IMPACT, PLASTIC. A collision between two bodies whose **coefficient of restitution** has a value less than unity. In such a collision kinetic energy is lost. The amount of energy lost is given by the formula:

$$\Delta K = \tfrac{1}{2}M_1(e^2 - 1)u_{1c}^2 + \tfrac{1}{2}M_2(e^2 - 1)u_{2c}^2$$

where M_1 is the mass of the first body, M_2 is the mass of the second body, e is the coefficient of restitution between the two bodies, u_{1c} is the final velocity of the first body with respect to center of mass, u_{2c} is the final velocity of the second body with respect to center of mass.

The total momentum remains unchanged in a plastic impact. (See **coefficient of restitution; center of mass coordinates; impact.**)

A collision in which the coefficient of restitution is zero is often called a perfectly inelastic impact.

IMPACT RADIATION. See **impact fluorescence.**

IMPEDANCE. The complex ratio of a force-like quantity (force, pressure, voltage, temperature or electric field strength) to a related velocity-like quantity (velocity, volume velocity, current, heat flow, or magnetic field strength). The terms and definitions under the term "impedance" pertain to single-frequency quantities in the steady state, and to systems whose properties are independent of the magnitudes of these quantities. These quantities can be represented mathematically by complex exponential functions of time. Under these conditions the factors involving time cancel out in the ratios called for, leav-

ing complex numbers independent of time. Solutions based on complex exponential functions under these conditions give the solution for real sinusoidal oscillations. Because of the similarity of electrical, mechanical, and acoustical transmission theory, the same terminology is used in the three cases. Where confusion is likely to occur, the proper term should be prefixed to the general term, e.g., acoustic transfer impedance. For example, while acoustics is a branch of mechanics, it is found convenient to distinguish an acoustic system from a mechanical one whenever elastic wave motion is an essential feature. While a strict application of the impedance concept implies the restrictions given above, it is common practice to extend the term "impedance" to situations involving nonsinusoidal quantities or nonlinear systems. Such extensions should be accompanied by an explanatory statement. (See also **impedance, acoustic; impedance electrical; impedance, mechanical;** and other specific entries under this heading.)

IMPEDANCE, ACOUSTIC. The acoustic impedance of a sound medium on a given surface lying in a wave front is the complex quotient of the **sound pressure** (force per unit area) on that surface by the flux (**volume velocity,** or linear velocity multiplied by the area), through the surface. When concentrated, rather than distributed, impedance of a portion of the medium is defined by the complex quotient of the pressure difference effective in driving that portion, by the flux (volume velocity), the acoustic impedance may be expressed in terms of mechanical impedance, acoustic impedance being to the mechanical impedance divided by the square of the area of the surface considered. The commonly used unit is the **acoustical ohm.** Velocities in the direction along which the impedance is to be specified are considered positive. This definition pertains to single-frequency quantities in the steady state and to systems whose properties are independent of the magnitudes of these quantities. Various other definitions have been proposed, but their application has been less widespread: (a) the quotient of the force by the **particle velocity** (Crandall); (b) the quotient of the sound pressure by the **volume displacement** (Webster); (c) the quotient of the sound pressure by the particle velocity (Brillié).

IMPEDANCE, ACOUSTIC, MEASUREMENT BY ACOUSTICAL METHOD. A method, due to Stewart, in which measurement is made of the change in acoustical transmission through a long uniform tube when the unknown acoustic impedance (see **impedance, acoustic**) is inserted as a branch.

IMPEDANCE, ACOUSTIC, MEASUREMENT BY IMPEDANCE TUBE METHOD. A method in which the acoustical material is used as the termination of a long tube. By means of a movable probe connected to a pressure microphone, amplifier, detector and meter, the difference in **decibels** between maximum and minimum sound pressure can be measured. The impedance of the sample can then be calculated from this standing wave ratio. (See **wave, standing.**)

IMPEDANCE, BLOCKED. Of a **transducer,** the impedance at the input when the impedance of the output system is made infinite. For example, in the case of an electromechanical transducer, the blocked electric impedance is the impedance measured at the electric terminals when the mechanical system is blocked or clamped; the blocked mechanical impedance is measured at the mechanical side when the electric circuit is open-circuited.

IMPEDANCE, CHARACTERISTIC (OF A CIRCULAR WAVEGUIDE). For the dominant (TE_{11}) mode of a lossless circular **uniconductor waveguide** at a specified frequency above the **cut-off frequency,** (1) the ratio of the square of the rms voltage along the diameter where the electric vector is a maximum to the total power flowing when the guide is match-terminated, (2) the ratio of the total power flowing and the square of the total rms longitudinal current flowing in one direction when the guide is match-terminated, (3) the ratio of the rms voltage along the diameter where the electric vector is a maximum to the total rms longitudinal current flowing along the half surface bisected by this diameter when the guide is match-terminated. Under definition (1) the power $W = V^2/Z_{(W,V)}$ where V is the voltage, and $Z_{(W,V)}$ the characteristic impedance defined in (1). Under definition (2) the power $W = I^2Z_{(W,I)}$ where I is the current and $Z_{(W,I)}$ the characteristic impedance defined in (2). The characteristic impedance $Z_{(V,I)}$ as defined in (3) is the geo-

metric mean of the values given by (1) and (2). Definition (3) can be used also below the cut-off frequency.

IMPEDANCE, CHARACTERISTIC (OF A RECTANGULAR WAVEGUIDE). For the dominant (TE_{10}) mode of a lossless rectangular **uniconductor waveguide** at a specified frequency above the **cut-off frequency,** (1) the ratio of the square of the rms voltage between midpoints of the two conductor-faces normal to the electric vector, and the total power flowing when the guide is match-terminated, (2) the ratio of the total power flowing to the square of the rms longitudinal current flowing on one face normal to the electric vector when the guide is match-terminated, (3) the ratio of the rms voltage between midpoints of the two conductor-faces normal to the electric vector to the total rms longitudinal current flowing on one face when the guide is match-terminated. Under definition (1) the power $W = V^2/Z_{(W,V)}$ where V is the voltage, and $Z_{(W,V)}$ the characteristic impedance defined in (1). Under definition (2) the power $W = I^2Z_{(W,I)}$ where I is the current and $Z_{(W,I)}$ the characteristic impedance defined in (2). The characteristic impedance $Z_{(V,I)}$ as defined in (3) is the geometric mean of the values given by (1) and (2). Definition (3) can be used also below the cut-off frequency.

IMPEDANCE, CHARACTERISTIC (OF A TWO - CONDUCTOR TRANSMISSION LINE). For a traveling, transverse **electromagnetic wave,** the ratio of the complex voltage between the conductors to the complex current on the conductors in the same transverse plane, with the sign so chosen that the real part is positive.

IMPEDANCE, CHARACTERISTIC WAVE. For a traveling **electromagnetic wave** at a given frequency, the ratio at a point of the complex magnitude of the transverse electric vector to that of the transverse magnetic vector, with the sign so chosen that the real part is positive.

IMPEDANCE CIRCLE. Consider a nondissipative **transmission line** terminated by a fixed **impedance.** As the line length is varied, the (complex) input impedance describes a circle in the R, X plane.

IMPEDANCE CONCEPT IN WAVE PROPAGATION PROBLEMS. The concept of **impedance** in **lumped-element networks** can be extended to be useful in wave propagation problems. In the case of a transmission line having voltage V across the line, and current I along the line, the impedance per unit length is

$$Z = \frac{1}{I}\frac{\partial V}{\partial X}.$$

In a homogeneous medium, plane waves are propagated like waves along a line of characteristic impedance E/H. This extension of a network concept is very useful for dealing with reflection and transmission at a discontinuity, such as a change of medium, or a change of size of a **waveguide.**

IMPEDANCE, DRIVING-POINT. At a driving point of a **transducer,** the complex ratio of the applied sinusoidal potential difference, force, or pressure to the resultant current, velocity, or volume velocity, respectively, at this point, all inputs and outputs being terminated in any specified manner.

IMPEDANCE, ELECTRICAL. The (complex) ratio of **voltage** to **current** in an **alternating-current circuit:**

$$\mathbf{Z} = R + jX = \frac{\mathbf{E}}{\mathbf{I}} = \frac{\mathbf{E}_1\epsilon^{j\omega t}}{\mathbf{I}_1\epsilon^{j\omega t}}.$$

The voltage and current are written in standard cissoidal form, $\mathbf{E}_1$ and $\mathbf{I}_1$ are complex **amplitudes** (to include magnitude and phase), R is called the resistance, and X, the reactance.

IMPEDANCE, FREE. Of a **transducer,** the impedance at the input of the transducer when the impedance of its load is made zero. The approximation is often made that the free electric impedance of an electroacoustic transducer designed for use in water is that measured with the transducer in air.

IMPEDANCE, FREE MOTIONAL. Of a **transducer,** the complex remainder after the blocked impedance has been subtracted from the free impedance.

IMPEDANCE, INPUT. The **impedance** presented by the **transducer** to a source, or by a **network** to the "input terminals" of a device.

IMPEDANCE, ITERATIVE. Of a **transducer,** that impedance which, when connected to one pair of terminals, produces a like impedance at the other pair of terminals.

IMPEDANCE LEVEL. The value of circuit **impedance** which is used in matching several **networks** to each other or to their terminal impedances is called the impedance level in that part of the circuit.

IMPEDANCE, LOADED. Of a **transducer,** the impedance at the input of the transducer when the output is connected to its normal load.

IMPEDANCE, MATCHED. That impedance which, when connected to a **transducer,** will cause maximum power transfer.

IMPEDANCE, MECHANICAL. The complex quotient of the alternating force applied to a system by the resulting linear velocity in the direction of the force at its point of application. The unit is the **mechanical ohm.**

IMPEDANCE, MOTIONAL (LOADED MOTIONAL IMPEDANCE). Of a **transducer,** the complex remainder after the blocked impedance has been subtracted from the loaded impedance.

IMPEDANCE, NORMALIZED (WITH RESPECT TO A WAVEGUIDE). An impedance divided by the **characteristic impedance** of the **waveguide.**

IMPEDANCE OF NETWORK BRANCH. The impedance of a **network branch** is the (complex) ratio of the voltage across the branch to the current through the branch. The voltage and current are both expressed as complex numbers.

IMPEDANCE OF TRANSMISSION LINE, INPUT. The **impedance** between the input terminals with the generator disconnected.

IMPEDANCE, SPECIFIC ACOUSTIC (UNIT AREA ACOUSTIC IMPEDANCE). At a point in the medium, the complex ratio of **sound pressure** to particle velocity. (See **velocity, particle.**)

IMPEDANCE, SURFACE TRANSFER. When an **electromagnetic wave** is guided along the surface of a conductor having finite conductivity, the ratio of tangential electric field at the surface to the current in the conductor is called the surface transfer impedance.

IMPEDANCE, SYNCHRONOUS. The source **impedance** of an **alternator,** at operating frequency. It depends both on the stationary impedance of the machine, and its **armature reaction** effects.

IMPEDANCE, THROAT ACOUSTIC. The acoustic impedance (see **impedance, acoustic**) at the input end of a horn.

IMPEDANCE, TRANSFER. Between two points of a **transducer,** the complex ratio of the applied sinusoidal potential difference, force, or pressure at one point to the resultant current, velocity, or volume velocity at the other point, all inputs and outputs being terminated in any specified manner.

IMPEDANCE, WAVE. See **wave impedance.**

IMPEDANCES, CONJUGATE. Impedances having resistance components which are equal and reactance components which are equal in magnitude but opposite in sign. Conjugate impedances are expressible by **conjugate** complex quantities.

IMPEDANCES, IMAGE, OF A TRANSDUCER. The **impedances** which will simultaneously terminate all of the inputs and outputs of the **transducer** in such a way that at each of its inputs and outputs the impedances in both directions are equal.

IMPEDED HARMONIC OPERATION. Synonym for **harmonics, suppressed.**

IMPEDOMETER. An impedance-measuring device for the very-high-frequency band and above, which consists of two **directional couplers** and a **voltage probe** in a short transmission line.

IMPEDOR. A circuit element having **impedance.**

IMPERFECTIONS IN SOLIDS. Many properties of solids depend on the presence of structural imperfections, that is, deviations from a perfect homogeneous crystal lattice. Such properties include **luminescence, atomic diffusion, color center** absorption, **crystal growth, plasticity, semiconduction,** etc. The various types of imperfection fall into groups, of which the main ones are **vacancies, inter-**

stitial atoms, dislocations, and foreign atoms, or **impurities.** One might also refer to **mosaic structure, polygonization, growth spirals, slip lines,** and other macroscopic features. The term imperfection is not usually applied to the **thermal vibrations** of the lattice, since these must be present in the most perfect lattice.

IMPLODE. A verb describing the violent shattering of a vessel or container in which the internal pressure is less than the external, e.g., in a highly-evacuated **cathode-ray tube** when the glass envelope is suddenly broken. Due to the atmospheric pressure against all sides of the tube, the glass moves inward with tremendous force.

IMPORTANCE FUNCTION, NUCLEAR. A measure of the importance to the chain reaction in a nuclear reactor of a neutron at a given position and with a given velocity. The relative importance of two types of neutrons, A and B, is given by the number of neutrons of type A that must be supplied to make up for the removal of one neutron of type B, the process being carried out so that the level of the chain reaction is not affected. The **iterated fission expectation** is a particular normalization of the importance function.

IMPROPER. See **fraction; integral, improper.**

IMPROVEMENT THRESHOLD. In angle-modulation systems (see **modulation, angle**), the condition of unity for the ratio of peak carrier voltage to peak noise voltage, after **selection** and before any nonlinear process such as **amplitude limiting** and **detection.**

IMPULSE. A vector quantity defined by the time integral of the force **F** acting on a particle over a finite interval, for example,

$$\int_{t_1}^{t_2} \mathbf{F}dt$$

for the interval from t_1 to t_2. The impulse-momentum theorem states that the impulse equals the change in momentum experienced by a particle during the corresponding time interval.

IMPULSE EXCITATION. A method of producing **oscillator current** in a circuit in which the duration of the impressed voltage is relatively short compared with the duration of the current produced.

IMPULSE GENERATOR. A device for producing very short pulses of high voltage, usually by charging capacitors in parallel and discharging them in series.

IMPULSE NOISE. See **noise, impulse.**

IMPULSE SEPARATOR. In television, a **synchronizing-signal** separator.

IMPULSE TRANSFORMER. See **peaking transformer.**

IMPULSE WHEEL OR PELTON WHEEL. One of the two principal types of turbines, in which the whole available **head** is transformed into kinetic energy before reaching the wheel. The wheel is so shaped and run at such a speed that the fluid leaving the wheel is moving very slowly, having communicated nearly all its kinetic energy to the moving wheel.

IMPULSIVE SOUND(S). Sounds that consist of short bursts rather than sustained tones. Examples are hand clap, typewriter noise, syllabic sound.

IMPULSIVE SOUND EQUATION.

$$\frac{E}{V} = e^{\frac{c\bar{\alpha}S}{4V}},$$

where E is the total sound energy produced by a single impulse, V is the volume of room, $\bar{\alpha}$ is the mean **sound absorption coefficient,** S is the exposed surface area, t is the duration of impulsive sound, and c is the velocity of sound.

IMPURITY, ACCEPTOR. See **acceptor impurity.**

IMPURITY, CHEMICAL. An atom within a crystal which is foreign to the crystal.

IMPURITY, DONOR (IN A SEMICONDUCTOR). An impurity which may induce **electronic conduction.** The mechanism involves thermal ionization of the donor, with the transfer of an electron to the **conduction band.**

IMPURITY HARDENING. See **Cottrell hardening.**

IMPURITY LEVELS. Energy levels outside the normal **band scheme** of a solid due to the

presence of impurity atoms. Such levels are capable of making an insulator semiconducting. (See **acceptor impurity; impurity, donor.**)

IMPURITY SEMICONDUCTOR. See **semiconductor, impurity.**

IMPURITY, STOICHIOMETRIC. A crystalline imperfection arising from a deviation from **stoichiometric** composition

INCH. Unit of length, abbreviation in. (1) Br. One thirty-sixth of an Imperial yard. (2) U.S. Exactly 1 meter/39.37 (Bureau of Standards); exactly 2.54 centimeters (American Standards Association).

INCIDENCE, ANGLE OF. The angle at which one body or material or radiation strikes a surface, measured from the line of direction of the moving entity to a line perpendicular to the surface at the point of impact. The term is used commonly in regard to the impact of radiant energy upon a material surface.

INCIDENT WAVE. See **wave, incident.**

INCLINED PLANE. A simple machine in which the force required to lift an object through a given vertical distance is reduced by constraining the motion of the object to an inclined plane The idealized mechanical advantage is equal to the reciprocal of sin θ, where θ is the angle of inclination to the horizontal.

INCLINED-TUBE MANOMETER. See **manometer, inclined-tube.**

INCLINOMETER. See **dip-needle.**

INCOHERENT SCATTERING. See **scattering, incoherent.**

INCOMPRESSIBLE VOLUME. That portion of the total volume of a gas which consists of the actual bulk of the gas molecules, rather than the spaces between molecules. It is because of the large amount of empty space between molecules that gases are easily compressible; the ideal gas law describes the behavior of a (hypothetical) gas which has no incompressible volume. Denoted by the quantity b in the **van der Waals equation.** (See **co-volume.**)

INCONGRUENT MELTING. In some systems, solid compounds are formed that do not melt to a liquid having the same composition, but instead decompose before such a melting point is reached. Thus,

$$3Al_2O_3 \cdot SiO_2 \rightarrow Al_2O_3 + \text{Solution.}$$

INCREMENTAL INDUCTANCE. See **inductance, incremental.**

INDEPENDENT FISSION YIELD. See **fission yield, independent.**

INDEPENDENT PARTICLE MODEL OF NUCLEUS. See **nucleus, independent particle, model of.**

INDEPENDENT VARIABLE. (1) For the mathematical meaning of this term, see **function.** (2) That independent quantity or condition which, through the action of the control system of an **automatic controller,** directs the change in the **controlled variable** according to a predetermined relationship.

INDETERMINANCY PRINCIPLE. A postulate of quantum mechanics that asserts that in the simultaneous determination of the values of two canonically conjugated variables, the product of the smallest possible uncertainties in their values is of the order of magnitude of the Planck constant h. If Δq is the range of values that might be found for the coordinate q of a particle, and Δp is the range in the simultaneous determination of the corresponding component of its momentum p, then $\Delta p \cdot \Delta q = h$. Similarly if ΔE and Δt are the uncertainties in the simultaneous determination of the energy and the time, $\Delta E \cdot \Delta t = h$.

INDETERMINATE FORM. Limiting processes applied to special combinations of functions sometimes result in meaningless expressions such as $0/0$, ∞/∞, $0 \cdot \infty$, $\infty - \infty$, 1^∞, 0^0, ∞^0, etc. These are called **indeterminate forms.** The method of differential calculus may be used to interpret such expressions (See **L'Hospital's rule.**)

INDETERMINATE STRUCTURE. A statically indeterminate structure is one which cannot be solved by the equations for static equilibrium. These equations state that the components of the forces acting on a body, taken in any two directions, must be equal to zero and that the sum of the moments of these same forces, taken around any moment center, must equal zero. If the axial stresses in the members of a structure are changed by

altering the length of one of the members a very small amount the structure is classified as indeterminate.

When there are more **reactions** than equations for static equilibrium the structure is externally indeterminate. After these reactions have been calculated the stresses in the members of the structure become statically determinate unless internally indeterminate, that is, contain redundant members.

In general, statically indeterminate structures can be analyzed by methods such as the energy theory or the deflection theory, although some are so complicated that the analyst must resort to experimental methods. The analysis of any indeterminate structure requires a knowledge of the size, shape and elastic properties of the individual members.

Examples of indeterminate structures are triangular frameworks containing redundant members, rigid frames having **loads** transmitted by the rigidity of the joints, fixed or 2 hinged arches, suspension bridges with stiffening **trusses,** building frames under the action of lateral forces, beams with built-in end supports, beams fixed at one end and simply supported at the other end and beams continuous over a number of supports.

INDEX. (1) An **integer** placed above a radical sign to indicate the root which is to be extracted. It is usually omitted for a square root. (2) An **exponent.** (3) A superscript or subscript used in the symbol for a **tensor.** A repeated index is called a **dummy** or **umbral index,** see **summation convention.** (4) In **group theory,** the order of the group divided by the order of a **subgroup.**

INDEX OF MODULATION. See **modulation factor.**

INDEX OF REFRACTION. (1) The velocity of radiation *in vacuo* divided by the velocity of the same radiation in a specified medium. Because of the **Snell law,** index of refraction may also be defined as the ratio of the sine of the **angle of incidence** (*in vacuo*) to the sine of the **angle of refraction.** Because the index of refraction of air is only about 1.00029, index of refraction is frequently measured with respect to air rather than with respect to free space (vacuum). Excepting a few very special cases (x-rays; light in metal films) the index of refraction is a number greater than unity. A few representative values are:

$$n_{\text{water}} = 1.34, \quad n_{\text{glass}} = 1.5\text{–}1.9,$$

$$n_{\text{germanium}} = 4.25 \text{ (infrared radiation)}.$$

(2) The square root of the relative dielectric constant of a medium $\sqrt{\epsilon/\epsilon_0}$. The index of refraction is invariably a function of the frequency or wave length of the radiation. When definition (2) is used, the appropriate value of ϵ is often not the **permittivity** observed with static fields.

INDEX OF REFRACTION, COMPLEX. For absorbing media, it is sometimes convenient to use a complex index of refraction

$$n^2 = n^2(1 - i\kappa)$$

where n is the customary index of refraction, κ is the absorption index and i is the square root of -1. (See **absorption index.**)

INDEX OF REFRACTION, MODIFIED. In the **troposphere,** the **index of refraction** at any height increased by h/a, where h is the height above sea level and a is the mean geometrical radius of the earth. When the index of refraction in the troposphere is horizontally stratified, **propagation** over a hypothetical flat earth through an atmosphere with the modified index of refraction is substantially equivalent to propagation over a curved earth through the real atmosphere.

INDEX OF REFRACTION, RELATION TO DIELECTRIC CONSTANT. See **dielectric constant, relation to index of refraction.**

INDICATING INSTRUMENT. Any measuring device which may be read by the observation of the position of a pointer on a scale. Indicating instruments are distinguished from null instruments, in which the measurement is obtained by the adjustment of parameters to values indicative of the quantity being measured.

INDICATOR. A term used formerly in nuclear physics for **tracer.** The latter is now the more common usage.

INDICATOR TUBE. See **tube, indicator.**

INDICIAL ADMITTANCE OF A NETWORK. The **response,** as a function of time, to a **unit step stimulus.** Specifically, the current produced by a unit step of one volt.

INDICIAL EQUATION. In the solution of a **differential equation** in series the substitution

$$y = \sum_{k=0}^{\infty} a_k x^{k+s}$$

is made. When k is put equal to zero, the coefficient of the lowest power of x remaining is set equal to zero and this is the indicial equation, which serves to determine the values of s. They are called the **exponents** of the differential equation.

The indicial equation may be: (1) independent of s, in which case no series solution of the type assumed exists; (2) a **polynomial** in s, of degree equal to the order of the differential equation; depending on the nature of the roots of the indicial equation, there may then be n distinct series solutions of the differential equation or fewer; (3) the degree of the polynomial is less than the order of the differential equation and series solutions are again impossible, in the usual case.

INDIRECT SCANNING. See **scanning, indirect.**

INDIRECTLY-HEATED CATHODE. See **cathode, indirectly-heated.**

INDIUM. Metallic element. Symbol In. Atomic number 49.

INDUCED DIPOLE MOMENT. See **dipole moment, induced.**

INDUCED NOISE. A type of tube noise due to induced voltages in the electrodes, caused by ultra-high frequency components of the random **space-charge.**

INDUCED NUCLEAR DISINTEGRATION. See **reaction, nuclear.**

INDUCED POLARIZATION. The **polarization** brought about by the action of an electric field on a dielectric that does not contain permanent **dipoles.**

INDUCED RADIOACTIVITY. Radioactivity resulting from nuclear reactions. (See **reaction, nuclear.**)

INDUCTANCE. The inductance of a circuit (such as a coil) is the rate of increase in magnetic linkage with increase of current. If we have a coil of several turns, carrying a steady current, a certain magnetic flux will, as a result, be linked with the coil, depending upon the size and shape of the coil, the number of turns, and the material occupying the surrounding space. If the current is now slightly increased, the resulting increase in flux may or may not be proportional to the change in current; if not, we shall have to consider a very small increase in each. The "linkage" is the product of the flux through the coil by the number of turns. Since magnetic flux is ordinarily expressed in **maxwells** (emu) or **webers** (mks), the linkage may be expressed in maxwell-turns or weber-turns. The inductance unit called the **henry** corresponds to a rate of linkage increase of 10^8 maxwell-turns or one weber-turn per ampere of current. This is a rather large unit, hence the millihenry and microhenry are commonly used

The inductance of a coil wound on a ferromagnetic core depends on the magnitude of the current, because of **hysteresis** effects By convention, the inductance of such a coil is usually taken as

$$L = X/2\pi f$$

where X is the reactance (see **inpedance, electrical**) and f is the frequency. The impedance used in determining this reactance is taken as the ratio of the effective voltage to the effective current, neglecting harmonics produced by the variability of the inductance.

INDUCTANCE, CRITICAL. The minimum inductance required to prevent the current from going to zero during any part of the cycle in the **input choke** of a choke input filter for a full-wave rectifier circuit. The value of this inductance (in henries) is equal to the load resistance (ohms) divided by three times the supply frequency (radians per second). The input choke must have a value equal to or greater than the critical value if the best performance in the way of regulation is to be realized.

INDUCTANCE, INCREMENTAL. The inductance which an **iron-cored coil** will offer to a-c when it is superimposed on d-c through the coil. This condition occurs very frequently in communication and electronic circuits since many of these involve direct currents for establishing an operating point and then superimpose the a-c signal. The d-c produces a certain amount of saturation in the **core** so the flux conditions presented to the

a-c are not the same as if no d-c were present When the core is in this partially saturated condition the flux changes produced by the a-c are not as great as they would be otherwise and hence the back e.m f of the coil or its inductive effect is reduced. Since the actual inductance presented depends upon the degree of saturation the rating of a coil which is designed to carry both types of current should include both the d-c value of the current and the **inductance** (which is understood in this case to be the incremental inductance). The effect on incremental inductance is due to the change of the permeability of the core, the permeability which is effective in this case being called the incremental permeability It is given by

$$\mu_\Delta = \frac{\Delta B}{\Delta H}$$

where μ_Δ is the incremental permeability, ΔB the change in flux density produced by the a-c and ΔH the change in magnetizing force produced by the a-c

INDUCTANCE-TUBE MODULATION. See **reactance tube.**

INDUCTION. (1) The production of an **electric charge** or **magnetic field** in a substance by the approach or proximity of an electrified body, a magnet or any other source of an electric or magnetic field, the term induction implying that there is a relatively non-magnetized medium, between the body in which the electric or magnetic effect is induced and the electrified body, or other source of the electric or magnetic field (See **induction, electric; magnetic induction.**) (2) The "induction" of current in a conducting circuit by variation of the magnetic flux linking the circuit. (See **inductance.**) (3) **Nuclear induction.** (4) Mathematical induction (See **induction, mathematical.**)

INDUCTION ACCELERATOR. A **betatron** or **rheotron.**

INDUCTION, COEFFICIENTS OF. The charges on a set of conductors are linear functions of the conductor potentials:

$$q_1 = c_{11}V_1 + c_{12}V_2 + \cdots + c_{1n}V_n$$

$$q_2 = c_{21}V_1 + c_{22}V_2 + \cdots + c_{2n}V_n$$

$$q_n = c_{n1}V_1 + c_{n2}V_2 + \cdots + c_{nn}V_n.$$

The coefficients $c_{ij} = c_{ji}$ are known as "coefficients of induction." (See **potential, coefficients of.**)

INDUCTION COIL. A device for obtaining a high, intermittent voltage from a source of low, steady voltage, such as a battery. This is accomplished by electromagnetic induction. A coil of relatively few turns, called the primary, and provided with a soft iron core, is connected in series with the battery and with some form of interrupter which renders the

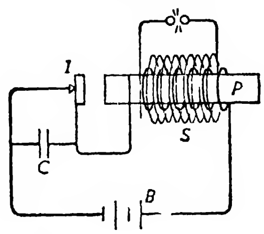


Diagram of induction coil showing its primary winding P its secondary winding S interrupter I, battery B and condenser C

current intermittent The rapid variations of magnetic flux thus produced give rise to correspondingly high electromotive forces in the secondary, a coil of many turns of fine wire wound on the same core and thus effectively coupled with the primary. The secondary electromotive force of course reverses with each make and break of the primary circuit The performance is improved by placing a **condenser** across the terminals of the interrupter.

INDUCTION COMPASS. See **compass, induction.**

INDUCTION-CONDUCTION HEATER. A heating device in which electric current is conducted through but is restricted by induction to a preferred path in a **charge (load).**

INDUCTION EFFECT. An attractive force between molecules, or a component of such force, due to the moment induced by an adjacent **dipolar** molecule.

INDUCTION, ELECTRIC. (Electric Displacement Density; **Electric Flux Density.**) (Symbol: **D**.) The electric induction in a dielectric is related to the charge separation produced by an applied field **E**. It is defined by **D** = ϵ**E**. The charge separation induced

on a conductor is controlled by **D**, rather than by **E**. Note that the electric field of a charge q immersed in a homogeneous dielectric medium is, in unrationalized systems,

$$E = \frac{q}{\epsilon r^2} \quad \text{so that} \quad D = q/r^2$$

and the total induced flux through any enclosing surface is $4\pi q$ irrespective of the dielectric. (See **current, displacement**; and **polarization, electric.**)

INDUCTION, ELECTRIFICATION BY. The proximity of positive charge to a conductor attracts negative charge to the nearby portions of the conductor, and leaves free, repelled positive charges These latter can be removed by temporarily "grounding" the conductor. Withdrawal of the proximate positive charge then leaves the conductor negatively charged, by "induction."

INDUCTION FIELD. A loop or coil carrying a steady, direct current is surrounded by a steady **magnetic field** which decreases with the cube of the distance. When sinusoidal current is passed through the coil, the resulting magnetic field oscillates with the same frequency as the current, and now comprises three components The first of these has an inverse-cube dependence on distance; it is given by the same formula as the field for steady current, but multiplied by an oscillating, sinusoidal factor. It is in phase with the current. Thus component is therefore often called the "quasi-static" field. One of the new components varies inversely with the square of the distance, and is in phase quadrature with the current. This phase quadrature implies zero **power factor**; the energy in this component flows alternately away from the coil and back into the coil, with no net loss. This component is called the "induction" field and is responsible for the characteristic back-voltage of an inductance, and the induction of emf in another coil by **mutual inductance.** The last new component varies inversely as the distance, and is in phase with the current The in-phase relation represents real power loss; the energy is radiated away from the coil, never to return. At relatively large distance, this component predominates; it is called the "radiation field."

INDUCTION FURNACE, HORIZONTAL-RING. A device for melting metal comprising an angular, horizontally-placed open trough or melting channel, a primary inductor winding and a magnetic core which links the melting channel with the primary winding.

INDUCTION GENERATOR. When an induction **motor** is driven by mechanical means above synchronous speed its **slip** becomes negative and the machine will act as a **generator** if it has the proper excitation. The induction generator draws its exciting current from the line, which puts a definite limit on the usefulness of the machine. For the line current to produce the correct field the load must take a leading current from the generator. This requirement for a **capacitive load** may be met by static **condensers** (almost never used) or synchronous machines on the line The speed of the induction generator does not determine the **frequency** which is fixed by synchronous machines on the same system.

INDUCTION HEATER, AUTOREGULATION. An induction heater in which a desired control is effected by the change in characteristics of a magnetic **charge (load)** as it is heated at or near its **Curie point.**

INDUCTION HEATER, DOMESTIC. A cooking device in which the utensil is heated by current, usually of commercial line frequency, induced in it by a primary inductor associated with it.

INDUCTION HEATER, MOTOR-FIELD. An **induction heater** in which the inducing winding typifies that of an induction motor of rotary or linear design.

INDUCTION HEATER OR FURNACE, CORE TYPE. A device in which a **charge (load)** is heated by induction and a magnetic core links the inducing winding with the charge.

INDUCTION HEATER OR FURNACE, CORELESS TYPE. A device in which a **charge** is heated by induction and no magnetic core material links the charge. Magnetic material may be used elsewhere in the assembly for flux-guiding purposes.

INDUCTION HEATER OR FURNACE, DUAL-FREQUENCY. A heater in which the charge receives energy by induction, simultaneously or successively, from a **load coil** or coils operating at two different frequencies.

INDUCTION HEATER OR FURNACE, HIGH-FREQUENCY. A device for causing induced electric current flow in a **charge (load)** to be heated, the frequency of the current being higher than that customarily distributed over commercial networks.

INDUCTION HEATER OR FURNACE, LOW-FREQUENCY. A device for inducing current flow of commercial power line frequency in a **charge** to be heated.

INDUCTION HEATING. The heating of a nominally conducting material in a varying **electromagnetic field** due to its internal losses.

INDUCTION, INTRINSIC (B_i) (INTENSITY OF MAGNETIZATION). The intrinsic induction or magnetic polarization of a medium is the vector difference between the **magnetic induction** at the point of interest, and the induction which would exist at that point, for the same **magnetizing force** if the medium were a vacuum there.

$$\mathbf{B} = \gamma_m \mathbf{H} + \mathbf{B}_i,$$

where γ_m is the magnetic constant (μ_0). In unrationalized systems of units the magnetic polarization is defined by

$$\mathbf{P}_m = \mathbf{B}_i / 4\pi,$$

whereas in rationalized systems,

$$\mathbf{P}_m = \mathbf{B}_i.$$

In any system, the polarization is related to the **magnetic moment density** by $\mathbf{P}_m = \gamma_m \mathbf{M}$.

INDUCTION LOUDSPEAKER. See **loudspeaker, dynamic.**

INDUCTION, MAGNETIC. See **magnetic induction.**

INDUCTION, MATHEMATICAL. A general method of proof in which a positive integral variable is involved. It consists of two main parts: (1) direct verification of the theorem for the smallest admissible value of the positive integer involved; (2) the algebraic proof that if the theorem is true for any value of the integer, it is true for the next greater value. In conclusion, the theorem is proved by combining the two parts.

INDUCTION MOTOR. See **motor, induction.**

INDUCTION, NUCLEAR. See **nuclear induction.**

INDUCTION-OUTPUT TUBE. See **tube, induction-output.**

INDUCTION, RESIDUAL. See **residual induction.**

INDUCTION-RING, HEATER. A form of core-type induction heater adapted principally for heating electrically conducting charges of ring or loop form, the core being open or separable to facilitate linking the charge.

INDUCTION THEOREM. Consider a medium comprising two homogeneous regions (which may have different or identical properties) separated by a closed surface S. An impressed electromagnetic field $\mathbf{E}_i$, $\mathbf{H}_i$ gives rise to an induced field; the induced field is composed of a field reflected from the surface and a field transmitted by the surface. The induced field is the same as that produced by electric and magnetic current-sheets on the surface, of densities

$$\mathbf{J} = \mathbf{n}_i \times \mathbf{H}_i$$

$$\mathbf{M} = \mathbf{E}_i \times \mathbf{n}$$

This is a consequence of the **Green theorem** applied to the **Maxwell equations.**

INDUCTION WATTHOURMETER. See **watthourmeter, induction.**

INDUCTIVE FEEDBACK. See **feedback, inductive.**

INDUCTIVE LOAD. An electrical load whose **impedance** has a positive imaginary component; i.e., it acts like a combination of resistance and inductance, as contrasted with resistance and capacitance. (Cf.: **capacitive load.**)

INDUCTIVE (SHUNT, COIL) NEUTRALIZATION. See **neutralization, inductive (shunt, coil).**

INDUCTIVE POST. See **post, inductive.**

INDUCTOMERIC EFFECT. A time-variable effect operating by the inductive mechanism; i.e., a general displacement of electrons in a molecule under the influence of electrical fields.

INDUCTIVE-RATIO BRIDGE. See **bridge, inductive-ratio.**

INDUCTOMETER. A variable **inductor,** used for varying the **inductance** in a **network,** as in balancing a bridge. It usually consists of two or more coils connected in series, the adjustment being accomplished by variation of their relative positions and hence of their mutual inductance(s).

INDUCTOR. (1) A device the primary purpose of which is to introduce **inductance** into an **electric circuit** or **network.** (2) A conductor or bundle of conductors on an electric machine in which voltage is induced by the cutting of lines of flux, e.g., the main conductors along the surface or in the slots of a generator **armature.**

INELASTIC COLLISION. See **collision, inelastic; impact, plastic.**

INELASTIC SCATTERING. See **scattering, inelastic.**

INEQUALITY. The notation $a < b$ means: a is less than b, and the notation $a > b$ means: a is greater than b. The notation $a \leq b$ means: a is either less than or equal to b; similarly for $a \geq b$. The rules for operating with these relations, which are called inequalities, are: (1) if $a < b$, and $b < c$, than $a < c$; (2) if $a < b$, then $(a + c) < (b + c)$; (3) if $a < b$ and $c > 0$, then $a \cdot c < b \cdot c$; (4) if $a < b$ and $c < 0$, then $a \cdot c > b \cdot c$. If the sense of the inequality is the same for all values of the symbols for which its members are defined, the inequality is called an absolute or unconditional inequality. If the sense of an inequality holds only for certain values of the symbols involved, but is reversed or destroyed for other values of the symbols, the inequality is called a conditional inequality. The sense of an inequality is not changed if both members are increased or decreased by the same number nor is it changed if both members are multiplied, or divided, by the same positive number. The sense of an inequality is reversed if both members are multiplied, or divided, by the same negative number. (See also **Bessel inequality; Schwartz inequality.)**

INEQUALITY OF CLAUSIUS. The **entropy** of a system undergoing an irreversible cyclic process tends to increase. This is one of the statements of the Second Law of Thermodynamics. (See **thermodynamics, second law of.)** It is equivalent to the statement that the entropy of the universe tends toward a maximum.

INEQUALITY THEOREMS, METHOD OF. A technique for the **X-ray analysis of crystal structure** in which use is made of certain fundamental inequalities, which must be satisfied by the **structure factors,** to estimate their phases.

INERTANCE, ACOUSTIC (ACOUSTIC MASS). The quantity which, when multiplied by 2π times the frequency, gives the acoustic reactance (see **reactance, acoustic**) associated with the highest energy of the medium.

INERTANCE, SPECIFIC. The coefficient which, when multiplied by 2π times the frequency, gives the positive imaginary part of the specific acoustic impedance. (See **impedance, specific acoustic.)**

INERTEEN. Trade name for an **Askarel** (chlorinated-synthetic) paper capacitor impregnant.

INERTIA. A property manifested by all **matter,** representing the resistance to any alteration in its state of motion. **Mass** is the quantitative measure of inertia.

INERTIA, MOMENTS AND PRODUCTS OF. In the general case of the motion of a particle or aggregate of particles with respect to a single fixed point, the angular momentum can be written as having three components with respect to a coordinate system based at the fixed point.

$$H_x = \omega_x \Sigma m_i(y_i^2 + z_i^2) - \omega_y \Sigma m_i x_i y_i - \omega_z \Sigma m_i x_i z_i$$

$$H_y = -\omega_x \Sigma m_i x_i y_i + \omega_y \Sigma m_i(x_i^2 + z_i^2) - \omega_z \Sigma m_i y_i z_i$$

$$H_z = -\omega_x \Sigma m_i x_i z_i - \omega_y \Sigma m_i y_i z_i + \omega_z \Sigma m_i(x_i^2 + y_i^2)$$

where ω_x, ω_y, ω_z = components of angular velocity, m_i = mass of ith particle, x_i, y_i, z_i = coordinates of ith particle.

The terms $\Sigma m_i(y_i^2 + z_i^2)$, $\Sigma m_i(x_i^2 + z_i^2)$, $\Sigma m_i(x_i^2 + y_i^2)$ are called moments of inertia with respect to the x, y, and z axes, respectively, and are symbolized by I_{xx}, I_{yy} and I_{zz}.

The terms $\Sigma m_i x_i y_i$, $\Sigma m_i x_i z_i$, etc., are called the products of inertia and are symbolized by I_{xy}, I_{xz}, etc.

For a continuous rigid body the summations are replaced by integrals over the volume of the body. In a rigid body, it is sometimes easier to choose coordinate axes, called moving axes, which are fixed in the body. There always exists one set of such axes, called principal axes, such that the products of inertia vanish and the angular momentum can be expressed in terms of the moments of inertia alone. The moments of inertia with respect to the principal axes are called the principal moments of inertia and possess either maximum or minimum values.

INERTIAL SYSTEM, THE PRIMARY. A reference system of coordinates based on the so-called "fixed stars."

INFINITE-IMPEDANCE DETECTOR. See **detector, infinite-impedance.**

INFINITE LINE. A theoretical transmission line of infinite length.

INFINITESIMAL. A quantity which may become smaller than any assigned number and thus become zero in the **limit.**

INFLECTION, POINT OF. A point on a curve, $y = f(x)$, where the second **derivative,** d^2y/dx^2, changes sign. Geometrically, it is the point at which a plane curve changes from concavity toward a fixed line to convexity toward it.

INFLECTION-POINT EMISSION CURRENT. That value of current on the **diode characteristic** for which the second derivative of the current with respect to the voltage is zero. This current corresponds to the inflection point of the diode characteristic, and is an approximate measure of the maximum space-charge-limited emission current.

INFORMATION, MEASURE OF. The **hartley.**

INFRA-BLACK REGION. The **"blacker-than-black"** region of a television signal corresponding to an illumination level below the level created by the **blanking signal.**

INFRARED ABSORPTION. The absorption of infrared radiation by crystals is due to the excitation of **lattice vibrations** in which ions of opposite charge move relative to one another (i.e., **optical modes**). Such vibrations occur in a relatively narrow band of frequencies, with a maximum at the *Reststrahl* wavelength.

INFRARED PHOTOGRAPHY. Infrared-sensitive films and plates may be divided into two classes: (1) materials of relatively high speed to the extreme red and infrared, i.e., from approximately 700 to 900 millimicrons, and (2) materials sensitive to much longer wavelengths but of lower sensitiveness. The former are used for general photography, for aerial photography and cinematography; the latter for spectoscopy in the infrared and other scientific applications requiring sensitivity to wavelengths longer than about 900 mμ. All infrared-sensitive materials are sensitive to violet and blue and to the extreme visible red as well. For true infrared photographs, a visually opaque filter transmitting the infrared only must be used. No filter, however, is required when photographing hot bodies such as an electric flatiron, hot castings, or high-pressure boilers, provided these show no visible glow. The limit of infrared photography is presently (1956) about 1200 mμ.

INFRARED PROBLEM. Consequence of **quantum electrodynamics** that, calculated to the lowest order, the cross-section for the production of low-energy photons in the **double Compton effect** and in **bremsstrahlung** diverges logarithmically. The difficulty disappears when **radiative corrections** to the theory of this process are computed.

INFRARED RADIATION. The band of electromagnetic wavelengths lying between the extreme of the visible (circa 0.75 microns) and the shortest microwaves (circa 1000 microns). Because many molecular-energy levels correspond to radiation in this range, infrared absorption spectra are of great use in chemical analysis, particularly of organic compounds. Since all bodies (not at absolute zero) radiate in this range, infrared systems

are of increasing importance to the military, since warm targets can be detected in the dark by their own radiation as distinguished from the necessity of illuminating a target to make it visible. Infrared radiation is sometimes incorrectly called "heat radiation" because warm bodies emit the radiation and bodies which absorb the radiation are warmed. However the radiation is not itself "heat."

The infrared region is sometimes subdivided as follows:

	Wavelength in Microns
Near infrared	Circa 0.75–3.0
Middle infrared	3.0–30.0
Far infrared	30.0–circa 1000

INFRASONIC FREQUENCY. See **frequency, infrasonic.**

INHOMOGENEOUS. The opposite of **homogeneous.**

INHOUR. A measure of nuclear **reactivity.** If zero reactivity is defined as that reactivity which causes a **nuclear reactor** to operate with constant power (infinite period), the reactivity in inhours is equal to the reciprocal of the reactor period, provided it is long.

"INHOUR" (INVERSE HOUR) FORMULA FOR NUCLEAR REACTORS. The inhour formula is

$$\rho_{Ih} = \frac{\dfrac{l}{Tk_{eff}} + \displaystyle\sum_{i=1}^{m} \frac{\beta_i}{1 + \lambda_i T}}{\dfrac{l}{3600k_{eff}} + \displaystyle\sum_{i=1}^{m} \frac{\beta_i}{1 + 3600\lambda_i}}$$

where ρ_{Ih} (in inhours) is the reactivity corresponding to a reactor period T (in seconds); l is the mean lifetime of thermal neutrons in the (finite) reactor; k_{eff} is the multiplication factor for the finite reactor; β_i is the fraction of total neutrons corresponding to the ith delayed neutron group, and λ_i is the decay constant (in sec^{-1}) of the ith delayed neutron group. Sometimes other formulas for reactivity are called the "inhour formula."

INITIAL IONIZING EVENT. In a radiation **counter tube,** any interaction by which one or more ions are produced, and which initiates a tube **count.**

INJECTION GRID. The grid in a **superheterodyne mixer** which injects the effect of the local **oscillator signal** into the electron stream. In tubes designed especially for this purpose, this grid has little or no interaction with the other grids.

INKOMETER. A device for measuring **adhesion** of liquids. The rotation of one drum transmits a torque to another by virtue of the liquid placed in contact with both, and the magnitude of the torque is measured.

INNER BREMSSTRAHLUNG. See **bremsstrahlung, inner.**

INNER QUANTUM NUMBER. See **quantum number, inner.**

INPUT CAPACITANCE (OF AN *n*-TERMINAL ELECTRON TUBE). The short-circuit **transfer capacitance** between the input terminal and all other terminals, except the output terminal, connected together. This quantity is equivalent to the sum of the **interelectrode capacitances** between the input electrode and all other electrodes except the output electrode.

INPUT EQUIPMENT. The equipment used for introducing information into a **computer.**

INPUT IMPEDANCE. See **impedance, input.**

INPUT IMPEDANCE OF A TRANSMISSION LINE. See **impedance of a transmission line, input.**

INPUT IMPEDANCE, TRANSISTOR. See **transistor parameter h_{11}.**

INPUT RESONATOR. The buncher resonator of a **klystron** or other velocity modulation tube.

INSCRIBER. See **input transcriber.**

INSERT EARPHONES. See **earphones, insert.**

INSERTION, D-C. See **d-c insertion.**

INSERTION GAIN, TRANSDUCER. The **gain** resulting from the insertion of a **transducer** in a transmission system, which is the ratio of the power delivered to that part of the system following the transducer, to the power delivered to that same part before insertion of the transducer. If the input and/or output power consists of more than one component, such as multifrequency signal or noise, then the particular components used and their weighting must be specified. This

gain is usually expressed in decibels. The "insertion of a transducer" includes bridging of an impedance across the transmission system.

INSERTION LOSS, TRANSDUCER. The loss resulting from the insertion of a **transducer** in a transmission system, which is the ratio of the power delivered to that part of the system which will follow the transducer, before insertion of the transducer, to the power delivered to that same part of the system after insertion of the transducer. This ratio is usually expressed in decibels. If the input power, or the output power, or both consist of more than one component, the particular components used must be specified.

INSERTION POWER GAIN OF AN ELECTRIC TRANSDUCER. The ratio of (1) the power developed in the external termination of the output with the transducer inserted between generator and output termination to (2) the power developed in the external termination of the output with the generator connected directly to the output termination.

INSERTION VOLTAGE OF AN ELECTRIC TRANSDUCER. The complex ratio of (1) the alternating component of voltage across the external termination of the output with the transducer inserted between the generator and the output termination to (2) the voltage across the external termination of the output when the generator is connected directly to the output termination

INSIDE SPIDER. The flexible centering device for the **voice coil** of a dynamic loudspeaker. (See **loudspeaker, dynamic.**)

INSOLATION. Solar radiation, as received by the earth or other planets; also, the rate of delivery of the same, per unit of horizontal surface.

INSTABILITY CONSTANT OF COMPLEX ION. See **ion, instability constant of complex.**

INSTANTANEOUS DISK. A recording disk designed to be played back immediately after recording.

INSTANTANEOUS FREQUENCY. See **frequency, instantaneous.**

INSTANTANEOUS POWER OUTPUT. See **output, instantaneous power.**

INSTANTANEOUS RECORDING. An **instantaneous disk.**

INSTANTANEOUS SOUND PRESSURE. See **sound pressure, instantaneous.**

INSTANTANEOUS SPEECH POWER. See **speech power, instantaneous.**

INSTRUCTION. Information which, when properly coded and introduced as a unit into a **digital computer,** causes it to perform one or more of its operations. An instruction commonly includes one or more **addresses.**

INSTRUCTION CODE. A code for representing the **instructions** which a particular **digital computer** can execute.

INSULATION, ELECTRIC. See **electric insulation.**

INSULATOR, ELECTRIC. A body of very low **conductivity** used to support or separate conductors without introducing an additional path for electric current.

INSULATOR, METALLIC. See **metallic insulator.**

INTEGER. A whole number.

INTEGRABLE SQUARE. A function $f(x)$ having the property that

$$\int f^*(x)f(x)dx < \infty$$

is **integrable square** (f^* is the complex **conjugate** of f).

INTEGRAL. (1) An **integer.** (2) In **calculus,** $\phi(x)$ is an integral of $f(x)$ if $d\phi/dx = f(x)$. The process of finding an integral is **integration** or the inverse of **differentiation.** If C is any real number, then $\phi(x) + C$ is also an integral of $f(x)$, the **integrand,** and C is a **constant of integration.** Thus, if one integral exists, an infinite number of others may be obtained by adding an arbitrary constant. These are called **indefinite integrals** and indicated symbolically as

$$\int f(x)dx = \phi(x) + C.$$

Elimination of the constant by appropriate means gives a **definite integral.**

INTEGRAL, CIRCULATORY. An integral of a **vector function F:**

$$\oint \mathbf{F}\cdot d\mathbf{s}$$

over a closed **contour.** It is a measure of the tendency of lines of force to close up. If **F** refers to a fluid, then the **circulatory integral** is a measure of the flow around the path chosen. When the vector field has a potential, this integral is zero and the field is said to be **irrotational.**

INTEGRAL, CONTOUR. See **contour.**

INTEGRAL, COSINE. See **integral, logarithmic.**

INTEGRAL, DEFINITE. The difference between values of an **indefinite integral** for two given values of the independent variable. The definite integral of $f(x)$ between the limits a and b is denoted by the symbol

$$\int_a^b f(x)dx.$$

Its properties include

$$\int_a^b f(x)dx = -\int_b^a f(x)dx;$$

$$\int_a^b f(x)dx = \int_a^c f(x)dx + \int_c^b f(x)dx.$$

INTEGRAL, ELLIPTIC. Any integral of the type

$$\int f(x, \sqrt{R}\,)dx,$$

where f is a **rational function** of its two **arguments** and R is a third or fourth degree **polynomial** in x, with no repeated roots. They may be reduced, by suitable change of variable, to a sum of elementary integrals and one or more of the following types:

$$u_1 = \int_0^x \frac{dt}{\sqrt{(1-t^2)(1-k^2t^2)}}$$

$$= \int_0^\phi \frac{dw}{\sqrt{1-k^2\sin^2 w}};$$

$$u_2 = \int_0^x \sqrt{\frac{1-k^2t^2}{1-t^2}}\,dt$$

$$= \int_0^\phi \sqrt{1-k^2\sin^2 w}\,dw;$$

$$u_3 = \int_0^x \frac{dt}{(t^2-a)\sqrt{(1-t^2)(1-k^2t^2)}}$$

$$= \int_0^\phi \frac{dw}{(\sin^2 w - a)\sqrt{1-k^2\sin^2 w}}.$$

These are **incomplete elliptic integrals** of the first, second, third kind, respectively When expressed in terms of $t = \sin w$, they are **Legendre's normal forms.** The constant k $(0 < k^2 < 1)$ is the **modulus** and a is an arbitrary constant. If $\phi = \pi/2$, the integrals are called **complete.**

Series evaluation of the elliptic integrals may be made and numerical tables for them are available They are called elliptic because they were first studied in order to determine the circumference of the ellipse

INTEGRAL EQUATION. The general linear equation, said to be of the third kind, is

$$g(x)\phi(x) = f(x) + \lambda\int_a^b K(x,z)\phi(z)dz$$

The known functions are $g(x)$, $f(x)$, and $K(x,z)$, the latter being called the **kernel** or **nucleus.** The limits of the integral, a and b, are either known functions of x or constants and λ may be either an absolute constant or a parameter. The unknown quantity, found by solving the integral equation, is ϕ as a function of the independent variable z

Special cases are **Fredholm** and **Volterra equations.** Non-linear equations also occur. If one or both limits, or the kernel, become infinite, the equation is **singular.** If $f(x) = 0$, the equation is **homogeneous.** General methods for solving integral equations include the **Liouville-Neumann series,** the **Fredholm method,** the **Schmidt-Hilbert method.**

A **differential equation,** together with its **boundary conditions,** may be formulated into a single expression as an integral equation. The resulting functions are particularly useful in **eigenvalue** or **Sturm-Liouville equations,** which frequently occur in mathematical problems. (See also **Abel integral equation.**)

INTEGRAL, EXPONENTIAL. See **integral, logarithmic.**

INTEGRAL, IMPROPER. If $f(x) \to \infty$ as $x \to a$, the integral

$$\int_a^b f(x)dx,$$

defined by

$$\int_a^b f(x)dx = \lim_{\delta \to 0} \int_{a+\delta}^b f(x)dx; \; \delta > 0$$

is an **improper integral.** Integrals of this kind are said to be convergent. Similarly, if $f(x) \to \infty$ as $x \to b$:

$$\int_a^b f(x)dx = \lim_{\delta \to 0} \int_a^{b-\delta} f(x)dx; \quad \delta > 0.$$

If $f(x) \to \infty$ as $x \to c$, where c is between a and b:

$$\int_a^b f(x)dx$$

$$= \lim_{\delta \to 0} \int_a^{c-\delta} f(x)dx + \lim_{\epsilon \to 0} \int_{c+\epsilon}^b f(x)dx.$$

These improper integrals are also called **convergent.**

INTEGRAL, INFINITE. If $f(x)$ is continuous for $x \geq a$ and if the definite integral

$$\int_a^t f(x)dx$$

approaches a limit as $t \to \infty$, this limit is denoted by

$$\int_a^\infty f(x)dx$$

and called an **infinite integral.** The integral

$$\int_{-\infty}^a f(x)dx$$

is defined in a similar way and

$$\int_{-\infty}^\infty f(x)dx = \int_{-\infty}^a f(x)dx + \int_a^\infty f(x)dx.$$

INTEGRAL, LINE. Suppose $\mathbf{r} = \mathbf{r}(t)$ determines a curve C in space and that $d\mathbf{r}$ is an infinitesimal **line element** of this curve. Three different **line integrals** may then be formed, using a **scalar** ϕ or a **vector V:**

$$(1) \int_C \phi d\mathbf{r}; \quad (2) \int_C \mathbf{V} \cdot d\mathbf{r}; \quad (3) \int_C \mathbf{V} \times d\mathbf{r}.$$

The results of integration are a vector, a scalar, a vector, respectively.

In each case, the line integral may be reduced to a sum of definite integrals and evaluated by the usual methods of **integral calculus.** The line integral may be generalized for the complex variable and the result is a **contour integral.**

INTEGRAL, LOGARITHMIC. The **definite integral**

$$li(z) = \int_0^z \frac{dt}{\ln t}.$$

If $z = e^x$, the function is also called the **exponential integral**

$$\mathrm{Ei}\,(ix) = \mathrm{Ci}\,(x) + i\,\mathrm{Si}\,(x) + \frac{i\pi}{2}$$

where Ci (x), Si (x) are the improper integrals called the cosine integral and sine integral, respectively:

$$\mathrm{Ci}\,(x) = -\int_x^\infty \frac{\cos t}{t} dt$$

$$= C + \ln x - \int_0^x \frac{(1 - \cos t)dt}{t}$$

$$\mathrm{Si}\,(x) = \int_0^x \frac{\sin t}{t} dt = \frac{\pi}{2} - \int_x^\infty \frac{\sin t}{t} dt$$

and C is the **Euler-Mascheroni constant.**

INTEGRAL, MULTIPLE. An expression requiring more than one **integration** in order to find the **integral.** (See **integral, surface** and **integral, volume.**)

INTEGRAL, PARTICULAR. An **integral** in which the **constant of integration** has been assigned some special value. The term usually refers to an integral found as the solution of a **differential equation.**

INTEGRAL, SINE. See **integral, logarithmic.**

INTEGRAL, SURFACE. To integrate a function $f(x,y)$ over a given **surface** in the XOY-plane, the methods of **calculus** show

that the result is a definite double integral, usually called the **surface integral**

$$\int_{a_1}^{a_2}\int_{b_1}^{b_2} f(x,y)dxdy$$

where the limits of the integration are chosen so that the entire surface S is covered. **Vector** methods are useful for discussing such integrals for the surface element $d\mathbf{S}$ may be treated as a vector, $d\mathbf{S} = d\mathbf{x} \times d\mathbf{y}$. If ϕ, $\mathbf{V}$ are **scalar, vector** functions, respectively, there are three possible surface integrals:

$$(1)\int_S \phi d\mathbf{S};\quad (2)\int_S \mathbf{V}\cdot d\mathbf{S};\quad (3)\int_S \mathbf{V}\times d\mathbf{S},$$

which give a vector, a scalar, a vector It is convenient to write only one integral sign, in general, and to understand by the symbol S that the limits of integration are suitably chosen.

In case (2), if $\mathbf{V}$ is the product of density and velocity of a fluid (or electric, magnetic, gravitational force; heat, etc.), the integral is the **flux** of $\mathbf{V}$ through the surface. (See also **area.**)

INTEGRAL, VOLUME. In elementary **calculus** the idea of a surface integral is extended to treat the case of the **volume** of a solid. If the bounding surface of the solid is given by $f(x,y,z)$, then the volume is the definite triple integral

$$\iiint dxdydz$$

where the limits of integration are chosen as required in each case In **vector** notation, the element of volume $d\tau = dxdydz$ is a **scalar.** There are thus two possible **volume integrals:**

$$(1)\int_\tau \phi d\tau;\quad (2)\int_\tau \mathbf{V}d\tau,$$

where ϕ is a scalar and $\mathbf{V}$, a vector. The integrals are, respectively, a scalar and a vector. As is frequently the custom, only one integral sign is used and the symbol τ as a reminder that the integration is triple and that appropriate limits of integration are to be supplied. (See also **volume.**

INTEGRAND. The quantity written behind an **integral** sign and thus any function which is to be **integrated.**

INTEGRATED X-RAY REFLECTION. A measure of the intensity of the beam of **X-rays** reflected by a given **atomic plane,** obtained by rotating the crystal through a small angle about the general direction of the beam, and averaging the intensity. This is necessary because the beam is never quite sharply defined, owing to **mosaic structure** in the cyrstal. It is usually written

$$\rho = E\omega/I$$

where E is the total reflected energy, ω the angular velocity of rotation, and I the total incident radiation energy per second.

INTEGRATING CIRCUIT. See **network, integrating.**

INTEGRATING FACTOR. A quantity which converts a differential equation into an **exact differential.** The equation is then integrable by **quadrature.**

INTEGRATING METERS. The ordinary electric service meter measures the total electric energy used over a period of time. It is in principle much like a **wattmeter,** except that the movable coil is replaced by a motor armature rotating against a magnetic damping arrangement The speed of revolution is proportional to the torque, which, in turn, is proportional to the product of current and electromotive force. The total revolution of the armature is recorded on dials by pointers suitably geared to the armature shaft Since angle = revolution speed × time, the reading of the dial is proportional to current × electromotive force × time, that is, to amperes × volts × hours or watt-hours. Other integrating meters may record such quantities as total charge

$$\int Idt$$

or magnetic flux

$$\int (d\mathbf{B}/dt)\, dt.$$

INTEGRATING NETWORK. See **network, integrating.**

INTEGRATING PHOTOMETERS. The usual types of photometer give the **luminous intensity** of a source as viewed from one direction only. A still more significant quantity is the mean spherical candle power, that is,

the average luminous intensity from all directions. To obtain such averages, some type of integrating photometer is used. The most common device at present is the "sphere" or "globe" photometer. This has a large hollow globe, painted white inside with barium sulfate paint. The lamp is mounted at any convenient point inside, and the resulting diffuse illumination of a transparent screen covering an opening in one side is measured by a photometer. (The screen must be protected from the direct rays of the lamp.) It was shown by Sumptner that under these conditions, the illumination on the screen is proportional to the mean spherical candle power, and is independent of the orientation or the position of the lamp.

INTEGRATION. The process of finding an **integral**, thus the process inverse to **differentiation**. If the integrand is simple in form, the integral may be solved by remembering what function would give the **integrand** by differentiation. In most cases, the integrand must be converted into one or more such elementary integrals by various means. These include: **integration by parts**; substitution of a new **variable**; conversion into **partial fractions**; use of **reduction formulas**. Collected results of this kind are found in tables of integrals.

If these devices fail, other possibilities include: **graphical** and **numerical integration**, **series integration**. (See also **quadrature**; **cubature**.)

INTEGRATION BY PARTS. If u and v are functions of a single independent variable, **differentiation** of their product gives $d(uv) = udv + vdu$. The inverse formula is that for **integration by parts**

$$\int udv = uv - \int vdu.$$

It frequently happens that a given function is not integrable directly but a solution may be found by this method. For a **definite integral** the formula may be written

$$\int_a^b f(x)dg(x) = [f(x)g(x)]_a^b - \int_a^b g(x)df(x).$$

INTEGRATION, GRAPHICAL. See **graphical integration.**

INTEGRATOR. A device whose output is proportional to the integral of an input signal.

INTELLIGENCE BANDWIDTH. The sum of the audio (or video) frequency bandwidths of the one or more channels.

INTELLIGIBILITY. See **articulation.**

INTELLIGIBILITY, DISCRETE SENTENCE. The per cent intelligibility (see **articulation**) obtained when the speech units considered are sentences (usually of simple form and content).

INTELLIGIBILITY, DISCRETE WORD. The per cent intelligibility (see **articulation**) obtained when the speech units considered are words (usually presented so as to minimize the contextual relation between them).

INTENSIFICATION. A process for increasing the density and contrast of a photographic image by depositing thereon silver, or a compound of mercury, copper, lead, uranium, or other metal. Intensification may also be effected by mordanting dyes to the image, but this method is not in general use.

INTENSIFIER ELECTRODE. See **electrode, intensifier.**

INTENSIFYING SCREEN. A fluorescent screen or layer placed in close contact with a photographic plate used in x-ray or ultraviolet work, the fluorescent light from which adds its effect to that of the invisible rays in producing an image on the plate.

INTENSITOMETER. A device for determining relative x-ray intensities during radiography, in order to control exposure time.

INTENSITY DIFFERENCE, MINIMUM PERCEPTIBLE. For any given frequency, the minimum difference in intensity of two sounds that can be distinguished by the human ear. (See **difference limen.**)

INTENSITY, ELECTRIC. See **field strength**; and **field, electric.**

INTENSITY LEVEL (SPECIFIC SOUND-ENERGY FLUX LEVEL) (SOUND-ENERGY FLUX DENSITY LEVEL). The intensity level, in decibels, of a sound is 10 times the logarithm to the base 10 of the ratio of the intensity of this sound to the reference intensity. The reference intensity shall be stated explicitly. In discussing sound meas-

urements made with pressure or velocity microphones, especially in enclosures involving normal modes of vibration or in sound fields containing standing waves, caution must be observed in using the terms "intensity" and "intensity level." Under such conditions it is more desirable to use the terms **pressure level** or **velocity level** since the relationship between the intensity and the pressure or velocity is generally unknown.

INTENSITY, LUMINOUS. The luminous flux (see **flux, luminous**) per unit solid angle emitted by a source.

INTENSITY METHOD OF MEASURING TOTAL ABSORPTIVITY. A method, due to Knudsen, of measuring the total absorptivity (see **sound absorption coefficient**) of a room, in which the maximum steady state energy density is measured before and after the addition of a known amount of absorption. The total absorptivity α can then be determined by the relation

$$\alpha = \frac{\alpha'}{\dfrac{E_{max}}{E'_{max}} - 1}$$

where E'_{max} is the maximum steady state energy density after α' units of absorption have been added.

INTENSITY MODULATION. See **modulation, intensity.**

INTENSITY OF A SPHERICAL SOUND WAVE, FORMULA FOR. The intensity of a spherical sound wave in a dissipative medium is given by

$$I = \frac{Pe^{-\alpha r}}{4\pi r^2},$$

where I = intensity in ergs/cm^2-sec, P = power output of source in ergs/sec, r = distance from source in cm, α = amplitude absorption coefficient in nepers/cm.

INTENSITY OF A SOURCE OF PARTICLES. The total number of particles emitted per unit area per unit time.

INTENSITY OF RADIATION. The energy or the number of photons or of particles, flowing through unit area per unit time. For parallel radiation, the area refers to a surface normal to the direction of propagation.

INTENSITY OF RADIOACTIVITY. The number of atoms disintegrating per unit time, or derivatively, the number of **scintillations** or other effects (**roentgens** per hour at one meter) observed per unit time.

INTENSITY, RADIANT (OF A SOURCE). The rate of transfer of radiant energy (see **energy, radiant**) per unit solid angle.

INTERACTION REPRESENTATION. Representation of the equations of motion, especially in **quantized field theory,** where the time dependence is carried partly by the **state vector** and partly by the operators (Cf. **Schrödinger representation, Heisenberg representation.**)

INTERACTION SPACE. In electron devices, the space between the electrodes in which energy is transferred to or from electrons.

INTERCARRIER NOISE SUPPRESSION. The partial or complete silencing of a receiver as it is being tuned between stations.

INTERCARRIER SOUND. The method employed in those television receivers which make use of the television picture carrier and the associated sound carrier to produce a frequency-modulated signal whose **center frequency** (or intermediate frequency) is equal to the difference between the two carrier frequencies.

INTERCHANGE. The mixing of **tracer** and added **isotopic carrier** such that the two participate to the same degree in any reaction, showing that mixing has occurred in whatever chemical forms the tracer may have originally been distributed.

INTERCOMMUNICATING SYSTEMS. Loudspeaking telephones for use in communicating between two rooms. The simplest systems consist of a master unit—amplifier, microphone, loudspeaker, and a talk-listen switch—and a remote unit—microphone, loudspeaker and a talk-listen switch.

INTERELECTRODE CAPACITANCE (*j*-*l*TH INTERELECTRODE CAPACITANCE C_{jl} OF AN *n*-TERMINAL ELECTRON TUBE). The capacitance determined from the short-circuit **transfer admittance** between the *j*th and the *l*th terminals. This quantity is often referred to as direct interelectrode capacitance.

INTERELECTRODE TRANSADMITTANCE (*j-l* INTERELECTRODE TRANSADMITTANCE OF AN *n*-ELECTRODE ELECTRON TUBE). The short-circuit **transfer admittance** from the *j*th electrode to the *l*th electrode.

INTERELECTRODE TRANSCONDUCTANCE (*j-l* INTERELECTRODE TRANSCONDUCTANCE). The real part of the *j-l* **interelectrode transadmittance.**

INTERFACE. A surface which forms the boundary between two phases or systems.

INTERFACIAL SURFACE ENERGY. The work required to increase an **interface** between two immiscible or partly miscible liquids by 1 cm^2.

INTERFACIAL TENSION. The contractile force of an interface between two liquids, resulting from their surface tensions, and the attraction between the molecules of the two liquids. It is commonly determined by measuring the **interfacial surface energy.**

INTERFERENCE. (1) The variation of wave amplitude with distance or time, caused by the superposition of two or more waves. As most commonly used the term refers to the interference of waves of the same or nearly the same frequency. Wave interference is characterized by the phenomenon of the occurrence of local maxima and minima of **wave amplitude,** which cannot be described by the ray approximation to solutions of the wave equation. In terms of the **Huygens approximation,** interference can occur whenever wave disturbance can be propagated from a source to a region of space by two or more paths of different length. There is (destructive) interference if the phases and amplitudes of the disturbances arriving by the various routes are such as to reduce the square of the resultant amplitude below the sum of the squares of the amplitudes of the components. Two or more sources may only be used if there is a fixed phase-relation between them. (2) Sound interference results when the waves concerned are **sound waves.** (3) Optical interference occurs with light waves. Thus, a beam of radiation may be separated into two parts, follow different paths and then brought back to form a single beam. Unless the two paths are of identical optical length, the two beams may not be in phase, and can destructively interfere at some points (dark) and constructively interfere at other points (bright). From the principle of conservation of energy, it is known that there is not a loss in energy due to interference. The energy missing at dark points will be found in the bright points. Interference patterns are commonly light and dark bands, all of equal width. Light beams which can cause interference patterns are called "coherent," while beams which cannot cause interference patterns are "incoherent." (4) In a signal transmission system, interference is either extraneous power which tends to interfere with the reception of the desired signals, or the disturbance of signals which results.

INTERFERENCE, ADJACENT-CHANNEL. Interference in which the extraneous power originates from a signal of assigned (authorized) type in an adjacent channel.

INTERFERENCE, CO-CHANNEL. Interference between two signals of the same type in the same radio channel.

INTERFERENCE ELIMINATOR. An **interference filter.**

INTERFERENCE FILTER. (1) A **filter** used to suppress man-made interference entering a receiver from the power line. (2) A filter which effectively increases the selectivity of a receiver, thus decreasing its sensitivity to strong adjacent-channel, **image** or **intermediate-frequency** transmissions. (3) An optical device which transmits only a narrow band of wavelengths, other wavelengths being suppressed by the destructive **interference** (3) of waves transmitted directly through the filter and those reflected $2n$ times, where n is an integer (from back and front faces of the filter).

INTERFERENCE FRINGES. See **interference (3).**

INTERFERENCE GUARD BANDS. See **bands, interference guard.**

INTERFERENCE MAXIMA AND MINIMA. See **interference (3).**

INTERFERENCE, OPTICAL. See **interference (3).**

INTERFERENCE, ORDER OF. See **order of interference.**

INTERFERENCE, SECOND - CHANNEL. **Interference,** in which the extraneous power originates from a signal of assigned (authorized) type in a channel two channels removed from the desired channel.

INTERFERENCE THRESHOLD. A measure of the signal-to-noise requirement for virtually error-free transmission and reception.

INTERFEROMETER, ACOUSTIC. A device for measuring velocity and absorption of sonic or ultrasonic waves in a gas or liquid. The waves are established by a vibrating quartz crystal, and the absorption or lack thereof is measured by observing the strength of the pattern of **standing-waves,** established in the medium between the sound source and a reflector, as the latter is moved, or the frequency is varied. The separation of peaks in the standing wave pattern provides information for determining the velocity at which the waves travel.

INTERFEROMETER, OPTICAL. Any arrangement whereby a beam of light from a large, luminous area (as a sodium flame) is separated into two or more parts by partial reflections, the parts being subsequently reunited after traversing different optical paths The two components then produce **interference.** The best known instrument is that of Michelson, shown diagrammatically in the accompanying figure The original beam *a* is

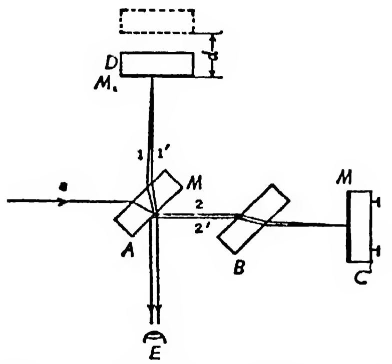


Diagram of Michelson interferometer

separated at the surface *AM* of a glass plate, part of it (1,1′) going to a mirror M_1 and part (2,2′) going on through a second, exactly similar plate B to the mirror M_2. They reunite at *AM* and are observed together at E. One of the mirrors, M_1, is mounted on a micrometer screw so that its distance from *AM* can be varied, the phase difference of the reunited beams thereupon passing through a series of cycles. If M_1 or M_2 is not quite perpendicular to the beam reflected by it, the field at E is crossed by interference fringes, which move across the field as the mirror M_1 is moved. Each complete cycle corresponds to a displacement of M_1 equal to a half-wavelength. The **Fabry and Perot interferometer** is somewhat simpler in design, but utilizes multiple reflection and produces very sharp fringes (high resolving power).

Interferometers are used for precise measurements of wavelength, for the measurement of very small distances and thicknesses by using known wavelengths, for the detailed study of the **hyperfine structure** of spectrum lines, for the precise determination of refractive indices, and, in astrophysics, for the measurement of **double-star** separations and the diameters of very large **stars.**

INTERGROWTH. See **overgrowth.**

INTERIONIC ATTRACTION THEORY. Even in concentrated solutions, there is a high degree of **ionization.** The reason, therefore, that the properties of strong electrolytes depart from those calculated under the **Arrhenius ionic theory** is not solely attributable to incomplete ionization, but involves the electrostatic attractions between ions of opposite charge, and the repulsions between ions of like charge. In solution, each positive ion is surrounded, on the average, with an **ionic atmosphere** of negative ions, and vice versa. (See also **theory of electrolytes.**)

INTERLACED SCANNING. See **scanning, interlaced.**

INTERMEDIATE FREQUENCY (IF). The frequency in **superheterodyne reception** resulting from a frequency conversion before **demodulation.**

INTERMEDIATE - FREQUENCY - HARMONIC INTERFERENCE. In **superheterodyne receivers,** interference due to radio-frequency circuit acceptance of harmonics of an intermediate-frequency signal.

INTERMEDIATE - FREQUENCY INTERFERENCE RATIO. See **intermediate-frequency response ratio.**

INTERMEDIATE-FREQUENCY RESPONSE RATIO. The ratio of (1) the **field strength** at a specified frequency in the **intermediate frequency band** to (2) the field strength at the desired frequency, each field being applied in turn, under specified conditions, to produce equal outputs.

INTERMEDIATE NEUTRONS. See **neutrons, intermediate.**

INTERMEDIATE STATE. The state of a superconducting material in an external magnetic field approaching the **critical field.** From the **Meissner effect,** magnetic flux becomes concentrated in certain regions, which become normal; the flux redistributes itself in such a way that the whole system has minimum free energy, the result being usually a complicated, fine-grained **domain** structure of alternately normal and superconducting regions.

INTERMEDIATE SUBCARRIER. A **carrier** which may be modulated by one or more **subcarriers,** and which is used as a modulating wave to modulate a carrier or another intermediate subcarrier.

INTERMETALLIC COMPOUND. In certain **alloy systems** distinct **phases** occur where the constituent atoms are in fixed integral ratios, e.g., CuZn (β-brass). Such a compound is held together by **metallic bonding** and may form a very complicated crystal structure. The constitution of such an alloy is often governed by the **Hume-Rothery rules.** In some cases, if the electron concentration is such as to just fill a band, the material may even be **semiconducting** (e.g., InAs).

INTERMITTENT-DUTY RATING. See **rating, intermittent-duty.**

INTERMITTENCY EFFECT. The departure from the **reciprocity law** when the **exposure** of a photographic emulsion is made in a series of discrete installments rather than in a continuous exposure to the same total energy.

INTERMODULATION. The **modulation** of the components of a complex wave by each other as a result of which waves are produced which have frequencies equal to the sums and differences of integral multiples of those of the components of the original, complex wave.

INTERMODULATION DISTORTION. Distortion resulting from **intermodulation.** In audio systems intermodulation distortion is measured in several different ways. One of the most common methods of measurement involves the determination of the rms value of all the sidebands produced when the system is simultaneously subjected to a low-frequency signal (40–100 cps) and a high-frequency signal (4000–8000 cps). By this method, percentage intermodulation is expressed as the ratio of the rms sideband voltages to the rms value of the high-frequency (carrier) frequency signal, when the magnitude of the high-frequency signal is one-fourth that of the low-frequency signal.

INTERMODULATION INTERFERENCE. Interference in superheterodyne receivers caused by the **intermodulation** of two undesired signals having frequencies which differ by an amount equal to the intermediate frequency. The intermodulation may occur in the **radio frequency amplifier,** the **mixer** or both.

INTERNAL COMBUSTION ENGINE. An engine in which **combustion** of a **fuel** takes place within the **cylinder,** and the products of combustion form the working medium during the power stroke.

INTERNAL CONVERSION. The emission of an electron called a conversion electron in the de-excitation of a nucleus by direct **coupling** between the excited nucleus and an extranuclear electron, commonly from the K-, L- or M-shell. Kinetic energy, equal in amount to the difference between the **transition** energy and the emitted electron's **binding energy,** is possessed by the electron. The direct emission of the **excitation energy** in the form of a gamma ray photon is a competing process. The internal conversion is followed by emission of **Auger electrons** or characteristic x-rays (see **x-rays, characteristic**) in consequence of the necessary rearrangement of the atomic electrons.

INTERNAL CONVERSION COEFFICIENT. (1) The ratio of the probability of an **internal conversion** transition between the same two states. This coefficient has different values for the ejection of electrons from the K, L, etc., shells, and the total internal conversion coefficient is the sum of the K, L, etc., conversion coefficients. (2) Formerly,

the internal conversion coefficient was defined as the probability that a **conversion electron** rather than a γ-ray photon would be emitted.

INTERNAL CORRECTION VOLTAGE. In an **electron tube,** the voltage that is added to the composite controlling voltage, and is the voltage equivalent of such effects as those produced by initial **electron velocity** and **contact potential.**

INTERNAL ENERGY. The energy ascribed to a given state of a system, which is determined only by the state itself (and is thus a scalar quantity) and is not accounted for by the kinetic energy of bulk motion or potential energy in external force fields By thermodynamics, the change in the internal energy when the system goes adiabatically from one state to another is equal to the external work performed in bringing about the change. On a molecular scale, the internal energy is the sum of the kinetic energy of the thermal motion of the molecules and the sum of their potential energies in each other's fields of force By the first law of thermodynamics, the change of internal energy in any process is equal to the difference of the heat gained and the external work done In this book the symbol U is used for internal energy; however, E is also in general use.

INTERNAL FRICTION. (1) The damping of elastic vibrations of a solid, i.e., **anelasticity.** (2) For internal friction of a liquid, see **viscosity.**

INTERNAL PRESSURE. See **pressure, internal.**

INTERNAL ROTATION, RESTRICTED. See **restricted internal rotation.**

INTERNAL STANDARD. (1) A material present in or added to samples in known amount to serve as a reference for spectral measurements. (2) An electrical component, such as a standard **cell,** or a standard **resistor,** built into an instrument to allow the instrument to be calibrated without the use of external standards.

INTERNAL STANDARD LINE. A **spectral line** of an internal standard, with reference to which the **radiant power** of an analytical line is measured.

INTERNAL TRANSMITTANCE. See **transmittance.**

INTERNATIONAL. When used before the name of an electrical unit, the term "International" indicates the unit accepted by the International Conference held in London 1908 and used as a legal unit prior to 1950. The relations of the International units to the present legal standards are treated in the Introduction.

INTERNATIONAL ANGSTROM. A unit of length used in measuring the wavelength of light and defined so that the wavelength of the red cadmium line shall be 6438.4696 International Angstroms. Note that the **angstrom** is ordinarily defined as 10^{-8} centimeters.

INTERNATIONAL RADIO SILENCE. Three-minute periods, starting 15 minutes and 45 minutes after the hour, when all radio stations (especially radiomarine) may cease transmission and listen to the international distress frequency of 500 kc

INTRANUCLEAR FORCES (n-p, p-p, n-n). It is believed that the attractive (n-n), (neutron-neutron), and (p-p), (proton-proton), forces are virtually equal, but that the latter is apparently decreased to some extent because of electrostatic repulsion between the protons. The (p-n), (proton-neutron), force is believed to be somewhat greater than the (p-p) or (n-n) forces.

INTERPHASE. The boundary surface between two **phases.**

INTERPHASE REACTOR. An **interphase transformer.**

INTERPHASE TRANSFORMER. A **transformer** (usually a center-tapped autotransformer) employed in some polyphase **rectifier circuits** to connect two points having the same average d-c potential, but different a-c potentials. The d-c current is customarily taken from the center tap of this transformer.

INTERPOLATION. A process by which an appropriate value is placed between tabulated, experimentally determined, or otherwise known values of a function. Linear interpolation is based on a principle of proportional parts; when the **variable (or argument)**

changes by a small amount, the change in the tabulated function is very nearly proportional to the change in the variable. For more accurate work, the relation between the two variables is usually approximated by a **polynomial,** and **finite differences** are used with formulas of **Newton, Lagrange, Bessel, Stirling,** etc.

INTERPOLATION, INVERSE. Given $y = f(x)$, in tabulated numerical form, a process of finding x for a value of y, intermediate between two tabulated values. Possible procedures include: **Lagrange's formula for interpolation;** successive approximations; **reversion of series** applied to other **interpolation formulas.**

INTERPOLATION, LINEAR. If (x_1,y_1) and (x_2,y_2) are neighboring entries in a numerical table, a value of the dependent variable y for a value of the argument x between x_1 and x_2 is given by

$$y = y_1 + \frac{(y_2 - y_1)}{(x_2 - x_1)} (x - x_1).$$

The procedure assumes that y varies **linearly** with x over the interval considered. It is commonly used for logarithms, trigonometric functions, etc., where the values of the argument are closely spaced.

INTERPOLE. An auxiliary pole placed between the main poles of a d-c **motor** or **generator** to give a flux which will aid in **commutation.**

INTERRUPTED CONTINUOUS WAVE. A wave which is the result of chopping up or interrupting a normal **continuous wave** radio signal at an audio rate. This interruption is distinct from the normal **keying** and is at a rate high enough to give several interruptions even for a dot of the International code. The result is an audio output from the **receiver** without the use of some method of **heterodyning.** The interruption of the wave, however, causes the radiation of many more **sideband** frequencies and hence the need of a wider **channel.** For this reason such transmissions are not widely used.

INTERRUPTED SPEECH. Speech signals used in intelligibility (see **articulation**) testing in which speech is regularly cut off for very short intervals, with a definite repetition rate.

INTERSTATION NOISE SUPPRESSOR. An intercarrier noise suppressor.

INTERSTICE. A small space within a **phase** or, more commonly, between particles.

INTERSTITIAL ATOM. An atom occupying an **interstitial position,** that is, squeezed between the regular lattice sites in a crystal. Such atoms form parts of **Frenkel defects.**

INTERSTITIAL COMPOUNDS OR STRUCTURES. Certain **crystal lattices** have quite large holes in them, in which it is possible to entrap other atoms of suitable dimensions. Even the inert gases may be bound into stable crystals in this way, with quite a large proportion of the vacancies actually filled.

INTERSTITIAL POSITION. A position not one of the proper **lattice sites** in a crystal.

INTERTRACTION. Increase in density of a **colloidal solution** caused by loss of solute by diffusion into a salt solution which is in contact with the colloidal solution.

INTERTROPICAL FRONT. See **front, intertropical.**

INTERVAL BETWEEN EVENTS. If two events occur at the positions and times represented by

$$x^\mu \text{ and } x^\mu + dx^\mu \ (\mu = 1, 2, 3, 4),$$

the interval between is given by

$$ds^2 = g_{\mu\nu} dx^\mu dx^\nu,$$

where $g_{\mu\nu}$ is the metric of space-time. In Minkowski space, the interval is given by:

$$ds^2 = c^2 dt^2 - dr^2.$$

INTERVAL-SELECTOR CIRCUIT. A time-selector transducer. (See **transducer, time-selector.**)

INTERVAL, SOUND. The interval between two sounds is their spacing in **pitch or frequency,** whichever is indicated by the context. The frequency interval is expressed by the ratio of the frequencies or by a **logarithm** of this ratio.

INTRINSIC COERCIVE FORCE. See **coercive force, intrinsic.**

INTRINSIC INDUCTION. See **induction, intrinsic.**

INTRINSIC MOBILITY. The **mobility** of electrons in an intrinsic semiconductor, or one having a very low concentration of impurity. It is limited only by scattering of the electrons by **thermal vibrations** of the lattice and varies as $T^{-3/2}$

INTRINSIC PROPERTIES (OF A SEMICONDUCTOR). The properties of a **semiconductor** which are characteristic of the pure, ideal crystal.

INTRINSIC SEMICONDUCTOR. See **semiconductor, intrinsic.**

INTRINSIC TEMPERATURE RANGE (IN A SEMICONDUCTOR). The temperature range in which the electrical properties of a **semiconductor** are essentially not modified by **impurities** or **imperfections** within the crystal.

INTRINSIC VISCOSITY. See **viscosity, intrinsic.**

INVAR. Trade name for a nickel alloy frequently employed in strain gauges, tuning forks and other applications, because of its extremely low temperature coefficient of expansion

INVARIANT. An expression involving the coefficients of an algebraic function which remains constant when a transformation, such as translation or rotation of coordinate axes, is made. (See **quadratic equation in two variables; discriminant; Lorentz transformation.**)

INVARIANT POINT. State of a given system where the number of degrees of freedom is zero, e g., the triple point: the condition that solid, liquid, and vapor phases shall exist in equilibrium completely determines the state of the system. (See **freedom, degree of (2)**.)

INVASION COEFFICIENT. A factor used to denote the number of milliliters of a gas under standard conditions absorbed by one square centimeter of surface in one minute.

INVERSE. If $y = f(x)$, the **inverse function** is $x = g(y)$. The inverse of an operation is one that undoes what has been done: addition, subtraction; multiplication, division; differentiation, integration.

INVERSE ELECTRODE CURRENT. See **electrode current, inverse.**

INVERSE HYPERBOLIC FUNCTION. If $y = \sinh z$, then z the inverse function is the angle whose hyperbolic sine is y and, in symbols, $z = \sinh^{-1} y$ = arc sinh y. From the definition of the **hyperbolic functions,** the following relations may be obtained:

$$\sinh^{-1} z = \ln (z + \sqrt{z^2 + 1})$$

$$\cosh^{-1} z = \ln (z \pm \sqrt{z^2 - 1})$$

$$\tanh^{-1} z = \frac{1}{2} \ln \frac{1 + z}{1 - z}$$

$$\coth^{-1} z = \frac{1}{2} \ln \frac{z + 1}{z - 1}$$

$$\operatorname{sech}^{-1} z = \ln \frac{1 \pm \sqrt{1 - z^2}}{z}$$

$$\operatorname{csch}^{-1} z = \ln \frac{1 + \sqrt{1 + z^2}}{z}.$$

INVERSE PHOTOELECTRIC EFFECT. See **photoelectric effect, inverse.**

INVERSE PLASTICITY. See **dilatancy.**

INVERSE TRIGONOMETRIC FUNCTION. The inverse function to $y = \sin z$ is the angle whose sine is y, or symbolically, z = arc sin $y = \sin^{-1} y$. Other inverse trigonometric functions are indicated in a similar way. If $y^2 < 1$, the following series expansions may be used:

$$\sin^{-1} y = y + \frac{y^3}{6} + \frac{1\cdot 3}{2\cdot 4\cdot 5} y^5 + \frac{1\cdot 3\cdot 5}{2\cdot 4\cdot 6}\frac{y^7}{7} + \cdots$$

$$= \frac{\pi}{2} - \cos^{-1} y$$

$$\tan^{-1} y = y - \tfrac{1}{3}y^3 + \tfrac{1}{5}y^5 - \tfrac{1}{7}y^7 + \cdots$$

$$= \frac{\pi}{2} - \cot^{-1} y$$

and, for $y^2 > 1$,

$$\tan^{-1} y = \frac{\pi}{2} - \frac{1}{y} + \frac{1}{3y^3} - \frac{1}{5y^5} + \cdots$$

$$\sec^{-1} y = \frac{\pi}{2} - \frac{1}{y} - \frac{1}{6y^3} - \frac{1 \cdot 3}{2 \cdot 4 \cdot 5y^5} - \frac{1 \cdot 3 \cdot 5}{2 \cdot 4 \cdot 6 \cdot 7y^7} + \cdots$$

$$= \frac{\pi}{2} - \csc^{-1} y.$$

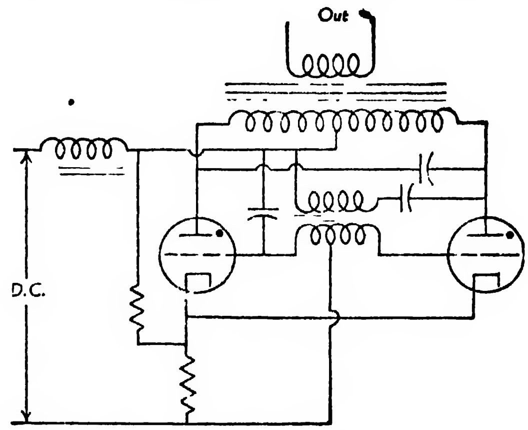
INVERSION. (1) The temperature below the **stratosphere** normally decreases with altitude. When temperature increases with altitude, normal conditions are inverted, and the condition is said to be an inversion. Inversions in the **troposphere** are usually restricted to shallow layers of air which most frequently occur in the lower 5000′ above the surface. In low latitudes the stratosphere has a slight inversion more or less permanently. (2) The transformation of an optically-active substance into one having the opposite rotatory effect, without essential change of chemical composition. (3) A form of speech-scrambling which essentially inverts the original frequency-spectrum of the signal. This may be accomplished by modulating the signal with a relatively low-frequency **carrier**, and then discarding the carrier and upper **sideband.** (4) The mathematical transformation of all points outside a circle or sphere into points inside, and vice versa. Each point at a distance r_1 from the center is mapped as a point at a distance r_2 from the center, lying on the same radius as the first point, with $r_1r_2 = r^2$, r being the radius of the circle. (5) See **Joule-Thomson inversion temperature.**

INVERSION, CENTER OF. See **symmetry, center of.**

INVERTED AMPLIFIER. See **amplifier, step-down.**

INVERTED SPEECH. The result of **inversion (3).**

INVERTER. A device for converting d-c into a-c but the term is commonly employed to designate a gas-filled electron-tube circuit for performing this function.



Self-excited parallel-type inverter

A basic self-excited inverter circuit is shown. This circuit is so set up that the tubes conduct alternately, causing the d-c to switch back and forth through the primary of the output transformer. This will induce a-c voltage in the secondary. There are numerous variations of inverter circuits but all use the tubes to switch the d-c supply back and forth to produce an a-c output.

INVOLUTION. The operation of raising numbers to powers. (See **evolution.**)

IODINE. Non-metallic element. Symbol I. Atomic number 53.

ION. An atom or molecularly-bound group of atoms which has gained or lost one or more electrons, and which has thus a negative or positive electric charge: sometimes a free electron or other charged subatomic particle Ions may be produced in gases by the action of radiation of sufficient energy; ionic solids are built up of ions bound together by their electrostatic forces, and when dissolved in a polar liquid, such as water, the salt dissociates into its ions, which have an independent existence.

ION, AMPHOTERIC. An **ion** which carries both a positive and a negative charge, commonly at opposite ends of a long, or fairly long, chain, as in the case of ions of **amino acids.**

ION, AQUO. A complex particle consisting of an ion combined with one or more molecules of water, as $H^+(H_2O)$ or H_3O^+. The strongly-ionizing solvents are considered to

form such complex ions with all, or virtually all, the ions in solution.

ION BEAM. A beam of charged particles other than electrons, all moving with essentially the same speed in a nearly common direction. Ion beams are produced by the application of electrical forces to ordinary ions and other particles, as in the production of a beam of α-particles by applying potentials in the millions of volts to the particles from a helium discharge tube; or as in the acceleration of ionic particles to great velocities by use of the **cyclotron.**

ION BEAM SCANNING. The process of analyzing the **mass spectrum** of an **ion beam** either by changing the electric or magnetic fields of the **mass spectrometer,** or by moving a probe.

ION BLEMISH, NEGATIVE. An **ion spot.**

ION BURN IN CATHODE-RAY TUBES. A deactivation of a small spot of the **phosphor** of a **cathode-ray tube,** caused by bombardment by heavy negative ions in the beam. The effect is noticeable only in **magnetic-deflection systems,** since an electrostatic deflection system deflects the negative ion through the same deflection angle as the electrons. Magnetic-deflection tubes require an **ion trap** to prevent permanent damage.

ION CLUSTER. A group of **ion pairs** produced at or near the point of a **primary ionizing event.** The ion cluster includes the primary ion pair (see **ion pair, primary**) and any secondary ion pairs formed, as by a **delta ray.**

ION, COMPLEX. A complex electrically charged radical or group of atoms such as $Ag(CN)_2^-$ or $Cu(NH_3)_2^{++}$, which may be formed by the addition to an ion of another ion or ions, or of an electrically-neutral radical or molecule.

ION-DIPOLE INTERACTION. A reaction between an **ion** and a dipole (i.e., a molecule having a **dipole moment**) which results in the formation of an aggregate of particles, in which the ion is at the center, surrounded by a number of molecules which are oriented so that their regions of polarity of sign unlike the charge of the ion, are closest to it. Thus, if the ion has a negative charge, the neighboring molecules will orient so that their regions of positive polarity are closest to the ion.

ION ENERGY SELECTOR. A dispersive device for **ion beams,** i.e., one which separates ions having different energies. One form consists of a pair of **capacitor plates** shaped like coaxial cylindrical shells. Ions with a given mass and initial velocity may be forced to travel in a circular course with radius r, between the shells, assuming the proper radius and potential difference between the plates.

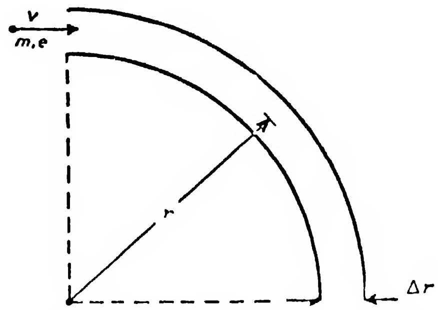


Diagram showing action of ion energy selector (By permission from "Electronics" by Williams, Copyright 1953, D. Van Nostrand Co., Inc.)

Ions with different mass or initial velocity experience different magnitudes of force than those mentioned above, and will not reach the exit before striking one of the shells. Thus the ions which do succeed in passing through will have approximately the same kinetic energy. This device is sometimes used as a part of a **mass spectrograph.**

ION EXCHANGE. A chemical process involving the reversible interchange of ions at a phase boundary, as between a solution and a particular solid material, such as an ion-exchange resin consisting of a matrix of insoluble material interspersed with fixed ions of opposite charge. Although most applications of the phenomenon occur in systems involving electrolyte solutions and ionic solids, the distribution of **electrolytes** between immiscible solutions of electrolytes, for example, may be considered an ion-exchange phenomenon.

ION, HETERO-. See **heteroion.**

ION, HYDRATED. See **hydrated ion.**

ION(S), INSTABILITY CONSTANT OF COMPLEX. The **dissociation constant** for the break-up of a **complex ion** into simple ions.

ION, MOLECULAR. A charged molecule, commonly produced by electrical discharges through gases in which a gaseous molecule has lost (or gained) one or more electrons.

ION, NEGATIVE. An ion carrying a negative charge; an **anion.**

ION PAIR. (1) A positive ion and a negative ion or electron, having charges of the same magnitude, and formed from a neutral atom or molecule by the action of radiation or by any other agency that supplies energy. (2) As postulated in the **Debye-Hückel theory**, in concentrated solutions of strong electrolytes (two or more), ions may occasionally approach each other so closely that they may form pairs (or groups) without entering into permanent chemical combination.

ION PAIR, PRIMARY. An **ion pair** (1) produced directly by the causative radiation.

ION-PAIR YIELD. The quotient of the number of molecules, M, of a given kind produced or converted divided by the number, N, of ion pairs resultant from high energy radiation. The M/N ratio.

ION, POSITIVE. An ion carrying a positive charge; a **cation.**

ION SPOT. See **ion burn in cathode-ray tubes.**

ION(S), STANDARD ENTROPY OF. The quantity called the standard **entropy** of an ion is really the relative partial entropy of the ion in a solution of unit activity, that of the hydrogen ion being assumed to be zero.

ION(S), STANDARD FREE ENERGY OF The **free energy** of formation of the particular ions, taking that for the formation of hydrogen ions at unit activity from the gas at 1 atmosphere pressure to be zero.

ION TRAP. An arrangement whereby the ions within an **electron beam** are prevented from bombarding the screen producing an **ion burn.**

ION TRAP, BENT-BEAM. An **ion trap** employing a bent electron-gun. The electrons are successfully deflected so that they pass through, while the ion beam strikes the side of the gun. (See **kinescope.**)

ION YIELD. The number of **ion pairs** produced per incident particle or quantum.

ION, ZWITTER-. See **zwitterion.**

IONIC ATMOSPHERE. As outlined under the definition of **Debye-Hückel theory of conductivity,** every ion attracts ions of opposite sign. Therefore, there are more ions of unlike than of like sign in the neighborhood of any individual ion in a solution and it is, in effect, surrounded by an ionic atmosphere of opposite charge.

IONIC BONDS. See **bond, electrostatic.**

IONIC CHARGE. Either the total charge carried by an ion, or the charge carried by an ion which has unit charge. Since ions owe their charges to gain or loss of electrons, unit charge is the charge on an **electron,** and all ionic charges are either equal in magnitude to this value, or integral multiples of it.

IONIC CRYSTAL. A crystal which consists effectively of **ions** bound together by their electrostatic attraction.

IONIC EQUILIBRIUM. In any **ionization,** at any particular temperature and pressure, the conditions at which the rate of **dissociation** of unionized molecules, or other particles to form ions, is equal to the rate of combination of the ions to form the unionized molecules, or other particles so that activities and concentrations remain constant as long as the conditions are unchanged.

IONIC FOCUSING. See **gas focusing.**

IONIC-HEATED CATHODE. See **cathode, ionic-heated.**

IONIC-HEATED CATHODE TUBE. See **tube, ionic heated cathode.**

IONIC MICELLES. Aggregates of **ions** exhibiting characteristic properties. The conception was applied by McBain to explain the behavior of soaps in very dilute solutions, in which aggregates of ten or more of the anions form ionic micelles containing a number of water molecules.

IONIC MIGRATION. The movement of charged particles of an **electrolyte** toward the electrodes under the influence of the electric current.

IONIC MOBILITY. (1) The ratio of the average drift velocity of an ion in solution

to the electric field. It is expressed by the relationship

$$\mu_+ \text{ or } \mu_- = \frac{\lambda_+ \text{ or } \lambda_-}{F}$$

in which μ_+ or μ_- is the mobility of the ion, λ_+ or λ_- is the ion conductance, i.e., the contribution of the particular ion to the equivalent **conductance,** and F is the **Faraday constant.** (2) For gaseous ions in an electric field, the quantity k defined by the relationship: $k = vp/E$, where v is the **drift velocity,** p, the gas pressure, and E, the electric field.

IONIC POTENTIAL. The ratio of the charge on an **ion** to its radius.

IONIC RADIUS. The repulsive force between two **ions** increases so rapidly at the distance at which their **electron shells** begin to overlap that it is possible to assign a more or less fixed radius to each ion These radii fix the dimensions and structure of **ionic crystals.** Values of ionic crystal radii have been calculated by Pauling (*Nature of the Chemical Bond,* Cornell University Press, 1945). Examples of their values (in Angstroms) are: Li^+, 0 60, Na^+, 0 95, K^+, 1 33, Rb^+, 1 48, Cs^+, 1.69; C^{4+}, 0 15, Si^{4+}, 0 41, Ti^{4+}, 0 68, Zr^{4+}, 0 80, Ce^{4+}, 1 01; C^{4-}, 2 60, Si^{4-}, 2.71, Ge^{4-}, 2.72, and Sn^{4-}, 2 94.

IONIC STRENGTH. A mathematical quantity used to evaluate the effectiveness of the forces restricting the freedom of **ions** in an **electrolyte,** and defined as one-half the sum of the terms obtained by multiplying the total concentration of each ion by the square of its valence, i.e., $\mu = \frac{1}{2}\Sigma c_i z_i^2$, where μ is the ionic strength, c is ionic concentration and z is valence.

IONIC SWITCH. See **transmit-receive switch.**

IONICITY OR DEGREE OF IONICNESS. A term applied to **Mullikan** to excited states, and denoting a fractional ionic character of the molecule in its ground state. Its numerical value depends upon the particular zero approximation used in defining it.

IONIUM. Naturally occurring radioactive nuclide. It is an isotope of **thorium** (atomic number 90) and has a mass number of 230.

IONIZATION. A process which results in the formation of **ions.** Such processes occur in water, liquid ammonia, and certain other solvents when polar compounds (such as acids, bases, or salts) are dissolved in them. Dissociation of the compounds occurs, with the formation of positively- and negatively-charged ions, the charges on the individual ions being due to the gain or loss of one or more electrons from the outermost orbits of one or more of their atoms. The ionization of gases is a process by which atoms in gases similarly gain or lose electrons, usually through the agency of an electrical discharge, or passage of radiation, through the gas.

IONIZATION BY COLLISION. The removal of an electron from an ion as the result of the energy gained in a collision with a body possessing sufficiently large energy.

IONIZATION BY ELECTRONS, PROBABILITY OF. The number of ions per unit **electron current,** per unit path length, per unit pressure at 0°C.

IONIZATION CHAMBER. One of a variety of enclosures used in the study of **ionized gases** or of ionizing agencies The essential features are a closed vessel containing a gas at normal or altered pressure, and furnished with two electrodes kept at different potentials These may be in the form of parallel plates or of coaxial cylinders, or one of them may be the vessel itself with the other inside and insulated from it. When the gas between the electrodes is ionized by any means, as by **x-rays** or **radioactive** emission, the ions move to the electrodes of opposite sign, thus creating an ionization current which may be measured by a **galvanometer** or an **electrometer.** (See also **counting tube.**)

IONIZATION CHAMBER, AIR-WALL. An **ionization chamber** in which the materials of the wall and electrodes are so selected as to produce ionization essentially equivalent to that in a free air ionization chamber. This is possible only over limited ranges of photon energies Such a chamber is more appropriately termed an air-equivalent ionization chamber.

IONIZATION CHAMBER, COMPENSATED. A device consisting of two **ionization chambers** connected in parallel, but with potentials reversed. One of these (the compensating chamber) is provided with a source of ionizing radiation such as uranium, which

can be so altered in position that the amount of ionization it produces in its chamber can be adjusted. The entire arrangement is then so balanced that the ionization received in the main chamber is exactly equal to that produced in the compensating chamber, and the instrument is used as a null indicator which shows both increases and decreases in the main chamber ionization from normal conditions.

IONIZATION CHAMBER COUNTING. The detection of radiation by means of an **ionization chamber**.

IONIZATION CHAMBER, DIFFERENTIAL. A two-section **ionization chamber** with the electrode potentials so arranged and controlled that the output current is equal to the difference between the separate ionization currents of the two sections.

IONIZATION CHAMBER, EXTRAPOLATION. An **ionization chamber** designed to make a series of measurements, in which one factor is varied in suitable steps. The data derived from these measurements are plotted in appropriate form and the desired result is obtained by **extrapolation** of the curve. The construction of such a chamber depends on the problem to be investigated

IONIZATION CHAMBER, FREE AIR. An air-filled **ionization chamber** in which a delimited beam of radiation passes between the electrodes without striking them or other internal parts of the equipment. The electric field is maintained perpendicular to the electrodes in the collecting region; as a result the ionized volume can be accurately determined from the dimensions of the collecting electrode and the limiting diaphragm, and the secondaries are produced only in air and are fully utilized. This is the basic standard instrument for x-ray dosimetry at least within the range from 5–400 kv.

IONIZATION CHAMBER, INTEGRATING. An **ionization chamber** whose collected charge is stored in a **capacitor** for subsequent measurement.

IONIZATION CHAMBER, PROPORTIONAL. An **ionization chamber** in which the initial ionization current is amplified by electron multiplication in a region of high **electric field strength, as it is in a proportional counter;** used for measuring ionization currents or charges over a period of time, and not for counting.

IONIZATION CHAMBER, PULSE. An **ionization chamber** employed to detect individual **ionizing events.**

IONIZATION CHAMBER, THIMBLE. A small cylindrical or spherical **ionization chamber,** usually with walls of organic material.

IONIZATION CURRENT. See **gas current.**

IONIZATION, DEGREE OF. The ratio, usually stated as a percentage, of the number or the concentration of the particles in a system which become ionized, to those which remain unionized. If the system is a solution, the reference particles are the molecules of a specified component.

IONIZATION, GASEOUS. The process by which charged particles are formed from neutral atoms or molecules of gases.

IONIZATION, MEAN FREE PATH. The average distance an electron must travel in the gas of a radiation **counter** before making an **ionizing collision** with a gas atom.

IONIZATION, MINIMUM. The smallest possible value of the specific ionization (see **ionization, specific**) that a charged particle can produce in passing through a particular substance. When the specific ionization produced along the path of a charged particle is plotted as a function of the particle energy, minimum ionization appears as a broad dip, bound on one side by a rather sharp rise for decreasing particle energy, and on the other side by a gradual rise for increasing particle energy. For singly-charged particles in ordinary air, the minimum ionization is about 50 ion pairs per centimeter of path. In general, it is proportional to the density of the medium and the square of the charge of the particle. It occurs for particles having velocities of 95% of the velocity of light, which corresponds to a kinetic energy of 1 mev for an electron, 2 bev for a proton and 8 bev for an α-particle.

IONIZATION POTENTIAL. The energy per unit charge, for a particular kind of atom, necessary to remove an electron from the atom to infinite distance. The ionization potential is commonly expressed in volts, and is numerically equal to the work done in removing the electron from the atom, expressed in electron-volts.

The difficulty in defining ionization potential arises from the fact that the ionization potential has perfectly definite values in the case of one-electron and two-electron configurations where the ionization process involves the removal of an s-electron. In the case of more complex configurations, such as the normal oxygen atom with its s^2p^4 electronic configuration, and five different orientations of the orbits and spins of the four p-electrons, the atom can be ionized in many different ways, each of which requires a slightly different energy, and hence represents a different ionization potential from all the others. It has therefore been proposed that the ionization potential be defined as the energy corresponding to the passage from the most stable state of the atom to the most stable state of the ion.

The first ionization potential is the energy to remove the most loosely bound electron from the neutral atom; the second ionization potential is the energy to remove the most loosely-bound electron from an atom from which one electron has already been removed, etc.

IONIZATION, SPECIFIC. The number of **ion pairs** formed per unit distance along the track of an ion passing through matter. This is sometimes called the total specific ionization to distinguish it from the primary specific ionization, which is the number of **ion clusters** produced per unit **track length.** The relative specific ionization is the specific ionization for a particle of a given medium relative either to that for (1) the same particle and energy in a standard medium, such as air at 15°C and 1 atm, or (2) the same particle and medium at a specified energy, such as the energy for which the specific ionization is a maximum. (See **ion; Bragg curve; ionization, minimum.**)

IONIZATION SPECTROMETER. See **Bragg spectrometer.**

IONIZATION TIME (OF A GAS TUBE). The time interval between the initiation of conditions for, and the establishment of conduction at some stated value of tube voltage-drop.

IONIZATION, TOTAL. (1) The total electric charge on the ions of one sign when the energetic particle that has produced these ions has lost all of its kinetic energy. For a given gas the **total** ionization is closely proportional to the initial energy and is nearly independent of the nature of the ionizing particle. It is frequently used as a measure of particle energy. (2) The total number of **ion pairs** produced by the ionizing particle along its entire path.

IONIZING ENERGY. The average energy given up by an **ionizing particle** in producing an **ion pair** in a specified gas.

IONIZING EVENT. An interaction by which one or more **ions** are produced.

IONIZING EVENT, INITIAL. An **ionizing event** that initiates a count in a radiation **counter tube.**

IONIZING EVENT, PRIMARY. The same as **ionizing event, initial.**

IONIZING PARTICLE. A particle that produces **ion pairs** directly in its passage through a substance. It usually is a charged particle, with a kinetic energy considerably greater than the **ionizing energy** of the medium.

IONOGENIC. Forming or furnishing **ions,** e.g., all **electrolytes.**

IONOSPHERE. The region of the atmosphere in which ionization exerts its greatest effect upon the radio frequency waves. This region lies between 30 and 250 miles (about 50 and 400 kilometers) above the earth's surface, with some seasonal and day-to-night variation.

IONOSPHERIC WAVE. A **radio wave** that is propagated by way of the **ionosphere.** This wave is sometimes called a sky wave.

IONS, DRIFT VELOCITY OF. The mean velocity with which ions move under the influence of an electric field.

IONS IN CHAMBER, MOBILITY OF. The mobility of ions in a gas is defined by the relationship:

$$v = \frac{kE}{p}$$

where v is the **drift velocity,** k is the **mobility** at unit pressure, E the electric field, and p the pressure.

IRE. Abbreviation for Institute of Radio Engineers.

IRIDESCENCE. The exhibition of the colors of the rainbow, commonly by interference of light of the various wavelengths reflected from superficial layers in the surface of a substance.

IRIDIUM. Metallic element. Symbol Ir. Atomic number 77.

IRIS DIAPHRAGM. (1) A diaphragm introduced into an optical system as a stop, and which is so constructed that the diameter of the opening may be changed continuously throughout a considerable range. The iris of the eye has this property, so as to keep the intensity of the light falling on the retina within proper bounds. The effective **f-number** of a good camera is changed by adjusting the iris diaphragm to a desired value to fit the **illumination** and **exposure time** to the sensitivity of the film used. (2) In a **waveguide,** a conducting plate or plates, of thickness small compared to a wavelength, occupying a part of the cross section of the waveguide. When only a single **mode** can be supported, an iris acts substantially as a **shunt admittance.**

IRON. Metallic element. Symbol Fe. Atomic number 26.

IRRADIANCE. See **radiant flux density.**

IRRADIANCE (OF A SURFACE). The radiant flux (see **flux, radiant**) incident per unit area of the surface.

IRRADIATION. Subjection to radiation, as for example, subjection to ultraviolet radiation for the formation of vitamin D from various sterols and related compounds.

IRRATIONAL. A number which is not an **integer** or a quotient of integers. An **irrational function** is one containing **radicals** and an **irrational equation** is one containing such functions.

IRREVERSIBLE PROCESS. A process occurring in a system such that, in order to reverse the direction of the process, a finite change in the parameters of the system must be made, e.g., the compression or expansion of a gas in a cylinder by means of a piston, when friction is present between piston and cylinder.

IS. Abbreviation for an **internal shield.**

ISENTROPIC CHANGE. A change that is accomplished without any increase or decrease of **entropy.**

ISOALLOBAR(S). Lines joining points having equal time rates of change of atmospheric pressure on a synoptic map (weather map).

ISOALLOBARIC FIELD. **Isoallobars taken** together constitute an isoallobaric field.

ISOBAR. (1) A line connecting points at equal pressure, such as that which appears on a meteorological chart. The pressures on such a chart are not the observed pressures, but are corrected for elevation, i.e., to sea level. (2) One of two or more atomic species, or elements, which have the same mass number, but which differ in other respects, such as atomic number. (See **isobar, nuclear.**)

ISOBAR, NUCLEAR. One of two or more **nuclides** having the same number of nucleons in their nuclei and therefore having identical **mass** numbers, and *about* the same **atomic mass.**

ISOBARIC. Occurring without change of pressure.

ISOBARIC SPACE. Defined under entry for **quantum number, isobaric spin.**

ISOBARIC SPIN QUANTUM NUMBER. See **quantum number, isobaric spin.**

ISOCHORE OR ISOMETRIC. A graph representing the state of a system as a function of two variables (e.g., pressure, temperature), the volume remaining constant. Hence any process that occurs without a change of volume.

ISOCHROMATIC. Of the same color, as of lines of the same tint in the interference figures of biaxial crystals.

ISOCHRONE. A line connecting points having the same time values, as points of the same gelation time for colloidal solutions.

ISODESMIC STRUCTURE. An **ionic crystal** structure in which there are no distinct groups formed within the structure. i.e., where no bond is stronger than all the others.

ISODIAPHERE. One of two or more **nuclides** having the same difference between the number of neutrons and protons in their nuclei.

ISODIMORPHISM (DOUBLE ISOMORPHISM). The condition in which both crystalline forms of a dimorphous substance which is isomorphous with a second dimorphous compound are **isomorphous** with both forms of the second compound. Example: arsenious oxide and antimonious oxide, which crystallize in rhombs and also in regular octahedra.

ISOELECTRIC POINT. In solutions of proteins and related compounds, the **hydrogen ion** concentration at which the dipolar **ions** are at a maximum is the isoelectric point. At this point the solution shows minimum **conductivity, osmatic pressure,** and **viscosity.** At this pH the protein shows the least swelling with water and does not undergo electrophoresis. That is, the colloidal particles move toward neither electrode. Proteins coagulate best and contain the least amount of inorganic matter at their isoelectric points.

ISOELECTRONIC. Pertaining to similar electronic arrangements. This term is applied, for example, to two or more atoms or atomic groups having an analogous arrangement of the same number of valency electrons, and similar physical properties.

ISOELECTRONIC SEQUENCE. A series of atoms having the same extranuclear electronic configuration.

ISOGONIC CHART. A chart showing lines of equal magnetic declination, or lines on which the variation of the magnetic needle from true north is the same. (See also **agonic line.**)

ISOLUX. A curve or surface of equal light **intensity.** (Also called **isophot.**)

ISOMAGNETIC. Lines connecting points at which some property of the earth's magnetic field (such as the magnitude, the vertical component, or the horizontal component) remains constant. Isomagnetic lines may indicate local magnetic anomalies such as caused by magnetic ore bodies, magnetic minerals in sediments, or the vertical rather than the horizontal deviation of the compass or magnetic needle.

ISOMER. (1) One of two or more substances which have the same elementary composition, but differ in structure, and hence in properties. (2) One of two or more nuclides which have the same mass number and atomic number, but differ in energetics and behavior. (See **isomer, nuclear.**)

ISOMER, NUCLEAR. One of two or more nuclides having the same **atomic number** and the same **mass number,** but existing for measurable time intervals in different states. One state, that of lowest energy, is the ground state; and all those of higher energy are metastable states. Metastable isomers are denoted by adding the letter m to the mass number where it appears in the symbol for the nuclide, as Br^{80m}.

ISOMER SEPARATION. The chemical separation of the lower energy member of a pair of nuclear isomers from its higher energy precursor, made possible by chemical changes occurring as a result of the atomic or molecular excitation associated with the isomeric transition.

ISOMERIC TRANSITION. A radioactive transition from a given nuclear isomer to one of lower quantum energy. The de-excitation of the nuclei in the metastable state may take place by gamma-ray emission, or by **internal conversion** followed by emission of x-rays and/or **Auger electrons.** It is a type of **forbidden transition.** (See **isomer, nuclear.**)

ISOMERISM, NUCLEAR. The occurrence of nuclear isomers. (See **isomer, nuclear.**)

ISOMERISM, OPTICAL. A type of **isomerism** in which the isomers are identical in composition, constitution, molecular weight, chemical properties, and most physical properties and differ only in the way their solutions (or liquid states) affect the rays of polarized light.

ISOMORPH. (1) One of two or more substances that crystallize in the same form. (2) One of a group of elements whose compounds with the same other atoms or radicals crystallize in the same form. The elements may be classified on this basis into eleven groups.

ISOMORPHISM. (1) Two **groups** G and G' are **isomorphous** if to each element A, B, C, $\cdots$ of G there corresponds an element A', B', C', $\cdots$ of G' so that if $AB = C$, then $A'B' = C'$, for every product. The isomorphism is simple if there is one unique element A in G for A' in G', but it may be multiple, i.e., several elements A_1, A_2, $\cdots$ may be iso-

morphous with one element A'. Mathematicians use the term homomorphism for this, restricting the term isomorphism to simple isomorphism. (2) A term applied to substances of different composition, which crystallize in the same form, or different elements which, when combined with the same atoms or radicals, crystallize in the same form.

ISOMORPHISM, CONDITIONS FOR. In order that two compounds be isomorphous, it is necessary that they have the same formula type, and that the respective structural units (atoms or ions) have the same relative sizes and the same polarization properties. For the formation of solid solutions or **overgrowths,** the **unit cell** dimensions must not differ by more than 10%.

ISOMORPHOUS SERIES TECHNIQUE. A method of **x-ray analysis** of **crystal structure** in which the change in the **x-ray diffraction** pattern when one atom is substituted for another is used to determine the phases. The two crystal structures must be identical in all respects, except for this substitution.

ISOPERIMETRIC PROBLEM. In the **calculus of variations,** the problem of making an integral **stationary,** while one or more integrals involving the same variables are to be kept constant (accessory conditions). It is so-called from a particular example, that of finding the figure of maximum area with a fixed **perimeter.** The method of **Lagrange's multipliers** may be used.

ISOPHOT. A curve or surface of equal light intensity. (Also called **isolux.**)

ISOPLERE. See **isochore.**

ISOPLETH. See **nomograph.**

ISOPOLYMORPHISM. The phenomenon of each of two forms of a *polymorphic* (see **polymorphism**) substance being *isomorphous* (see **isomorphism**) with two forms of another polymorphic substance, e.g., SnO_2 and TiO_2, which are isotrimorphous.

ISOPYCNAL. See **isochore.**

ISOSTERES. Pairs of compounds which show notable agreement in physical properties (as carbon dioxide and nitrous oxide; carbon monoxide and nitrogen) and which (according to the octet theory) have the same number and arrangement of electrons in the molecule. The term applies also to radicals and groups of atoms which hold pairs of electrons in common These are termed isosteric compounds, and the phenomenon is called isosterism (Langmuir).

ISOTEMPERATURE LOCI. Lines on a **chromaticity diagram** connecting points having equal correlated color temperatures. (See **temperature, correlated color.**)

ISOTENISCOPE. An instrument used to measure **vapor pressure.** It consists essentially of a U-tube containing the liquid of which the vapor pressure is to be measured. One arm of the tube connects with a closed vessel containing the same liquid; the other arm is connected to a manometer. The pressure in the latter is adjusted to the value at which the liquid levels in both arms of the U-tube are the same This is the vapor pressure of the liquid at the temperature of the test.

ISOTHERM(S). (1) Lines joining points of equal temperature. Isotherms can be drawn for any surface or cross-section. (2) More generally stated, a relationship, or its analytical or graphical expression, for which the temperature is constant.

ISOTHERMAL. (1) Of constant temperature. Isothermal processes are those conducted without temperature change. (2) A line or curve expressing a relationship between variables such as pressure and volume, for all values of which the temperature remains constant. (3) A line joining points at the same temperature.

ISOTHERMAL ATMOSPHERE. Any layer of air in which the temperature does not vary with altitude is known as an isothermal layer; if the whole atmosphere were of constant temperature in the vertical it would be an isothermal atmosphere.

ISOTHERMAL COMPRESSION. Compression during which the temperature remains constant. In general, this will entail flow of heat into or out of the system.

ISOTHERMAL EXPANSION. Expansion during which the temperature remains constant. In general, this will entail flow of heat into or out of the system.

ISOTONE. One of two or more **nuclides** having the same number of **neutrons** in their nuclei.

ISOTOPE. One or two or more nuclides having the same **atomic number,** hence constituting the same element, but differing in **mass number.** In addition to this fundamental meaning of the term isotope, it is used for certain specialized meanings. One of these is as a synonym for isotopic tracer, a radionuclide used as a tracer for a substance with which it is isotopic. Another is as a synonym for a preparation of an element with a special isotopic composition **(allobar)** as an article of commerce, which may also find use as an isotopic tracer.

ISOTOPE CHARTS (Z-*N*, Z-*A*, *A*-Z, *A*-2Z, TRILINEAR). Any of a set of charts in which the properties of atomic nuclei, including their modes of radioactive decay, are summarized. In the trilinear chart, the neutron number A-Z is plotted against the atomic number Z, the axes being inclined at an angle of 60 degrees; the result is that nuclides with the same mass number are found in the same vertical row, while each horizontal row contains species with the same neutron excess A-2Z.

ISOTOPE EFFECT. The effect of nuclear properties other than **atomic number** on the non-nuclear chemical and physical properties of nuclides, leading to variations in the properties of isotopes. Such effective nuclear properties are size, mass, spin, statistics, parity, magnetic dipole moment and electric quadrupole moment. Isotope effects can be observed in such properties as density, rate of diffusion, **isotope shift, equilibrium distribution** and **rate of reaction;** and they are utilized in isotope separation.

ISOTOPE EFFECT IN SUPERCONDUCTIVITY. The **critical temperature T_c of superconductors** varies with the isotopic mass M. The relation $T_c \propto M^{-1/2}$ suggests that the superconducting transition depends on the velocity of sound, a result predicted by the **Fröhlich-Bardeen theory.**

ISOTOPE SEPARATION. The field of knowledge and practice concerned with changing the relative abundances of **isotopes.**

ISOTOPE SEPARATION FACTOR. The ratio of the abundance ratio of two isotopes after processing to their abundance ratio before processing. It is given by the following equation:

$$r = \frac{n'_1/n'_2}{n_1/n_2}$$

where n_1 and n_2 are the mole fractions of isotopes of mass numbers m_1 and m_2 respectively, and n'_1 and n'_2 are the corresponding quantities after processing. The term "enrichment factor" is sometimes used for $r - 1$.

ISOTOPE SEPARATION METHODS. A number of methods have been developed for the separation of isotopes. These methods differ in their efficiency and applicability to various substances, although there are instances, notably the case of uranium-235—uranium-238, in which several of the methods have been successfully used in large scale separation of the same substances. Among the methods of isotope separation are:

(1) Separation by Centrifuge. A method in which a mixture of isotopes in the gaseous or liquid state is caused to spin at high speeds. The radial forces, which are very high compared to ordinary gravitational forces, cause an increase in concentration of the heavier isotopes near the periphery and correspondingly an increase in concentration of the lighter isotopes near the axis of the chamber.

(2) Separation by Diffusion Pumps. An application of the process of separation by diffusion through a gas, in which a gaseous isotopic mixture diffuses through a vapor stream into the jet of a diffusion pump. The lighter molecules are pumped preferentially by the streaming vapor, producing a separation effect.

(3) Separation by Diffusion Through Gas. A method in which a gas that is an isotopic mixture is allowed to diffuse through another (preferably heavier) gas. Separation of the various isotopes is based on the principle that the lighter isotopic molecules diffuse through the heavier gas more readily than the heavier isotopic molecules.

(4) Separation by Electrolysis. The separation of isotopes by electrolytic decomposition of a solution, as in the electrolysis of water for the concentration of deuterium. The method depends on the differing rates of discharge of isotopic ions, and hence is a function of the chemical properties of the different isotopes.

(5) Separation by Electromagnetic Method. A separation of ions of varying mass by a combination of electric and magnetic fields. In the most common application an isotopic mixture of ions is produced either by electron bombardment of a gas or by thermionic emission. The ionized particles are accelerated and collimated into a beam by a system of electrodes, and the beam is projected into a magnetic field where the paths of the ions depend on their mass-to-charge ratio. Properly located collectors can be placed to receive ions of specified masses. The foregoing method is based on the principle of the **mass spectrograph.**

(6) Separation by Fractional Distillation. A method whereby isotopes in liquid form are separated in a fractionating tower by evaporation and re-condensation. The distillation process results in an upward-directed stream of vapor and a downward-directed stream of liquid, the two being in intimate contact and constantly exchanging molecules.

(7) Separation by Gaseous Diffusion Through a Barrier. A method in which a gas that is an isotopic mixture is allowed to diffuse through a porous wall or barrier. Separation of the various isotopes is based on the principle that the lighter molecules, M_1, diffuse through the porous wall more readily than the heavier molecules M_2. The effective simple process factor is generally less than $\sqrt{M_2/M_1}$ because of insufficiently-long **mean free path,** back diffusion, impoverishment of gas in front of the barrier (cut correction, mixing inefficiency) etc.

(8) Separation by Ion Mobility. A process based on the difference in mobility of different ions in an electrolytic solution under the influence of an electric field

(9) Separation by Thermal Diffusion (see **Clusius column**). A method based on the observation that in many mixtures a temperature gradient causes the concentration of one type of molecule in the warmer region and of the other type in the colder region. In the Clusius column a temperature gradient is established between two concentric vertical cylinders, and the counter-current circulation set up by thermal convection produces cascading of the effect. Either a gas or liquid may be employed as the working medium.

ISOTOPE SEPARATIVE POWER. A measure of the useful amount of separation accomplished in unit time by a separative element. It is proportional to the circulation which can be handled and, for separation factors only slightly greater than one, to the square of the excess over unity of the effective simple process factor.

ISOTOPE SHIFT. In atomic spectroscopy, a slight difference in wavelength for a given spectral line of one **isotope** as compared with another.

ISOTOPE STRUCTURE. See **hyperfine structure (2).**

ISOTOPIC ABUNDANCE. The relative amount (expressed as number of atoms) of a particular isotope in a sample of an element.

ISOTOPIC ABUNDANCE, FRACTIONAL. The ratio of the number of atoms of a particular isotope to the total number of atoms of the element, both in a given sample. It is usually expressed as a percentage.

ISOTOPIC ABUNDANCE, RELATIVE. The number of atoms of a particular isotope relative to a specified number of atoms of a specified isotope, both in a given sample Usually the meaning is more specific, as the number of atoms of a particular isotope relative to 100 atoms of the most abundant isotope, or to 1 atom of the least abundant isotope.

ISOTOPIC ATOMIC WEIGHT. The comparative **atomic weight** of an **isotope,** or a distinct atomic species, calculated on the basis of an atomic weight of 16.0000 for the lighter isotope of oxygen This differs from the standard chemical practice, which uses as standard an atomic weight of 16.0000 for ordinary oxygen, which contains small percentages of isotopes having approximate isotopic atomic weights (mass numbers) of 17 and 18.

ISOTOPIC DILUTION ANALYSIS. A special method for determining the concentration of an **element** in a system. A compound containing a **radioactive isotope** of the element at known concentration is added to the system. A pure sample of the compound is then isolated from the system. From the decrease in activity of the tracer element the original concentration of the element in the system can be computed.

ISOTOPIC EXCHANGE. (1) A process whereby atoms of the same element in two

different molecules or in different sites in the same molecule exchange places. Thus

$$HC^{13}N_{(g)} + C^{12}N^-_{(aq)} \rightleftarrows HC^{12}N_{(g)} + C^{13}N^-_{(aq)}.$$

The equilibrium in such an exchange reaction is influenced slightly by the relative masses of the two atoms which exchange, and it forms the basis of one of the methods of isotope separation and concentration. (2) The transfer of isotopically tagged species, without net chemical reaction, from one chemical form or valence state of an element to another. This may come about by exchange of tagged atoms, by exchange of other atoms in the chemical complex or by transfer of electrons.

ISOTOPIC INDICATOR. The same as isotopic **tracer.**

ISOTOPIC MASS. A term formerly used for **atomic mass.**

ISOTOPIC NUMBER. The same as **neutron excess.**

ISOTOPIC SPACE. The same as isobaric space Defined under **quantum number, isobaric spin.**

ISOTOPIC SPIN QUANTUM NUMBER. The same as isobaric spin quantum number. (See **quantum number, isobaric spin.**)

ISOTOPIC TRACER. See **tracer.**

ISOTRIMORPHISM (TRIPLE ISOMORPHISM). The condition in which two isomorphous substances are each trimorphous and each of the three pairs of forms is isomorphous (Cf. **isodimorphism.**)

ISOTRON. A device for **isotope** separation based on the electrical sorting of ions. Ions of different mass accelerated to a given energy have different velocities. By synchronizing the field on a deflector grid to **pulses in the** ion source, ions of different velocities (hence different masses) may be collected.

ISOTROPIC MEDIUM. A medium whose properties are the same, in whatever direction they are measured. Such a medium has only two independent **elastic moduli** or **constants,** and only one **refractive index, dielectric constant, magnetic susceptibility,** etc

ISOTROPIC SOLIDS, ELASTIC PROPERTIES OF. See **Young modulus, Poisson ratio, compression modulus.**

ISOTROPISM. Possessing isotropic properties, i e , properties whose physical magnitude is independent of **orientation.**

ISOVOLUME. An **isochore.**

ITERATED FISSION EXPECTATION. In a **critical assembly,** the value after large time of the number of fissions per generation time arising from the daughter neutrons of a given neutron This is a specific normalization of the **importance function.**

ITERATIVE IMPEDANCE. That impedance which, when applied to one pair of terminals of a four-terminal **transducer** will cause the same impedance to appear between the remaining pair of terminals

ITERATION, METHOD OF. A process of successive approximations used in the numerical solution of **algebraic or transcendental equations, differential equations,** for **interpolation,** etc Suppose, for example, the real roots of a numerical equation $f(x) = 0$ are desired and that the equation can be written in the form $x = \phi(x)$. Find an approximate root x_0, graphically or otherwise, and calculate $x_1 = \phi(x_0)$, which is a better approximation than x_0. Continue, and calculate $x_2 = \phi(x_1)$; $x_3 = \phi(x_2)$; $\cdots$; $x_n = \phi(x_{n-1})$, until the required number of significant figures is obtained.

J

J. (1) Joule, (J). (2) Joule mechanical or electrical equivalent of heat, (J). (3) Radiant intensity (J), spectral radiant intensity (J_λ). (4) Heat transfer factor (J). (5) Gram-equivalent weight (J). (6) Action variable (J). (7) Electric current density $(\mathbf{J})$. (8) Imaginary unit, $\sqrt{-1}$, in electric circuits (j). (9) Polar moment of inertia (J). (10) Inner quantum number (quantized total angular momentum of electron) (j). (11) Total inner quantum number (quantized total angular momentum of systems of two or more electrons) (J). (12) Unit vector in y-direction $(\mathbf{j})$. (13) Total emissive power (J), monochromatic emissive power $(J_\lambda$ or $J_\nu)$.

J ANTENNA. See **antenna, J.**

***j-j* COUPLING.** See **coupling, *j-j*.**

JACK. A connecting device arranged for the insertion of a **plug.** One or two circuits may be carried by the jack and, in addition, it may perform one or more switching functions upon insertion or removal of the plug.

JACKFIELD. A field of **jacks.**

JACK-SCREW. A simple **machine** in which the force required to move an object is reduced by applying the force on a lever arm connected to a screw. The theoretical mechanical advantage is equal to $2\pi R/h$ where h is the pitch of a screw and R is the length of the lever arm. Because of friction the actual mechanical advantage is very much less than this.

JACOBI ELLIPTIC FUNCTION. If an incomplete elliptic integral of the first kind is indicated by z, then z is defined as a function of k and ϕ, where k is the **modulus** of z and ϕ is the **amplitude** of the integral. Calling the integral u, designating the **inverse function** $\phi = \text{am } u$, then $x = \sin$ (am u). The latter quantity, generally written $x = \text{am } u$, is a **Jacobian elliptic function.** Related ones are $\text{cn } u = \cos (\text{am } u) = \pm\sqrt{1 - x^2}$; $\text{dn } u = \pm\sqrt{1 - k^2x^2}$. They have simple **poles,** are doubly **periodic,** and are generalizations of the **trigonometric** and **hyperbolic functions,** which are singly periodic.

JACOBI POLYNOMIAL. A solution of the differential equation

$$x(1 - x)y'' + [c - (a + 1)x]y' + n(a + n)y = 0$$

with a, c real; $c > 0$; $a > (c - 1)$; n, an integer. The nth polynomial is given by the series

$$J_n(a,c,x) = 1 + \sum_{k=1}^{n} (-1)^k \binom{n}{k} \times \frac{(a + n)(a + n + 1) \cdots (a + n + k - 1)}{c(c + 1) \cdots (c + k - 1)} x^k$$

where c is not a negative integer. The polynomials are a special case of the **Gauss hypergeometric function**

$$J_n(a,c,x) = F(-n,a + n,c;x)$$

while the **Legendre** and **Tschebyscheff polynomials** are special cases of the Jacobi polynomials

$$P_n(x) = J_n(1,1,z); \quad T_n(x) = J_n(0,\tfrac{1}{2},z)$$

where $2z = (1 - x)$.

JACOBIAN. Let F_1 and F_2 be two functions of u and v. Then

$$J = \begin{vmatrix} \dfrac{\partial F_1}{\partial u} & \dfrac{\partial F_1}{\partial v} \\ \dfrac{\partial F_2}{\partial u} & \dfrac{\partial F_2}{\partial v} \end{vmatrix} = \frac{\partial F_1}{\partial u}\frac{\partial F_2}{\partial v} - \frac{\partial F_1}{\partial v}\frac{\partial F_2}{\partial u}$$

is the functional **determinant** or **Jacobian of F_1** and F_2 with respect to u and v. It is frequently denoted by $\partial(F_1,F_2)/\partial(u,v)$.

In general if $F_1, F_2, \cdots, F_n$ are functions of $u_1, u_2, \cdots, u_n$, then

$$J = \frac{\partial(F_1,F_2,\cdots,F_n)}{\partial(u_1,u_2,\cdots,u_n)}$$

$$= \begin{vmatrix} \frac{\partial F_1}{\partial u_1} & \frac{\partial F_1}{\partial u_2} & \cdots & \frac{\partial F_1}{\partial u_n} \\ \frac{\partial F_2}{\partial u_1} & \frac{\partial F_2}{\partial u_2} & \cdots & \frac{\partial F_2}{\partial u_n} \\ \cdot & \cdot & \cdots & \cdot \\ \frac{\partial F_n}{\partial u_1} & \frac{\partial F_n}{\partial u_2} & \cdots & \frac{\partial F_n}{\partial u_n} \end{vmatrix}.$$

(See also **Hessian.**)

JAEGER METHOD FOR SURFACE TENSION. A method whereby the pressure necessary to cause air to flow from a capillary tube immersed in the liquid is measured. It is particularly suitable for investigating the variation of surface tension with temperature.

JAEGER-STEINWEHR METHOD FOR MECHANICAL EQUIVALENT OF HEAT. A rise-of-temperature method similar to the **Griffiths method.** Improvements consist in (a) the use of a large mass of water, (b) small rise in temperature, (c) efficient stirring of the water and (d) controlled temperature of the surroundings.

JAMIN EFFECT. A **capillary** tube filled with a column of air bubbles separated by liquid can withstand a substantial pressure difference between its ends without continued flow. This resistance to flow arises from pressure differences due to **surface tension** which arise when the air-liquid interfaces are distorted by the initial displacement.

JAMMING. Transmission of a signal or signals to cause interference in the reception of another station or radar.

JEANS VISCOSITY EQUATION. An equation relating the **viscosity** of a gas to the temperature, having the form $\eta = kT^n$, where k is a constant, T is the absolute temperature, and n is an empirical constant differing for different gases.

JET. A jet is produced when fluid is discharged through an orifice into a free space. A liquid jet may be free if it is discharged into a gas or submerged if it is discharged into a body of the same liquid.

JET ENGINE. Technically this term might include any device for propulsion which uses the reaction force obtained from the acceleration of a fluid stream (see **jet propulsion**). In many engineering applications, the interest is in combustion jets, wherein the reaction of a powerful jet of products of combustion expelled rearward from the engine is the source of propulsion. Present-day jet engines meeting this specification are classified as follows: (1) Gas turbine systems or turbojets; (2) Resonance ducts; (3) Aero-thermodynamic ducts.

All of these draw in air for combustion from the surrounding atmosphere, and it is in this respect that they differ from rocket motors.

JET, GAS. As gas is a compressible fluid, the velocity attained in a jet cannot be evaluated from Bernoulli's principle. If one uses adiabatic expansion from P_1 to P_2 in a properly shaped nozzle, the ideal velocity of the gas jet is:

$$v = 8\sqrt{\frac{RT_1}{z}\left[1 - \left(\frac{P_2}{P_1}\right)^z\right]} \text{ ft per sec.}$$

R and z are characteristics of the gas, R being the common gas constant (i.e., 53.4 ft-lbs per degree for air), and z being $(c_p - c_v)/c_p$ wherein the c's are specific heats, B.T.U. per lb per degree, at constant pressure and constant volume.

$z = .286$ for air under 1000°F.
$z = .23$ to $.28$ for products of combustion of fuels.

T_1 is the absolute temperature at pressure P_1.

JET PROPULSION. Jet propulsion, as commonly practiced, is reaction propulsion. In other power plants where both action and reaction exist, it is the action that is sought for use, and the reaction claims attention chiefly on account of the need for providing anchorage or support. But jet propulsion *uses the reaction.*

JET STREAM. Two circumpolar air currents moving in a highly-irregular, periodically-variable, east-to-west direction. Their general location is about 35,000–55,000 ft above the earth's surface, and to middle-to-northern and middle-to-southern latitudes; thus the northern hemisphere jet stream passes over the United States and the Mediterranean, with loops much further north. The velocity varies from 100 to 500 miles per hour.

JETEC. Abbreviation for Joint Electron-Tube Engineering Council.

JITTER. Small, rapid variations in a **wave-form** due to mechanical disturbances or to changes in the supply voltages, in the characteristics of components, etc.

JOG. A step in a **dislocation line,** brought about by the intersection of dislocations with one another.

JOHNSON AND LARK-HOROWITZ FORMULA. A formula for the resistivity of a metal or **degenerate semiconductor** due to the presence of impurities which scatter the electrons. It may be written

$$\rho = 6270n^{-1/3} \text{ ohm-cm}$$

where n is the number density of impurity atoms per cm^3.

JOHNSON NOISE. See **noise, thermal.**

JOLY "BLOCK" SCREEN. A **bench photometer** head composed of two blocks of opal glass or paraffin with an opaque partition between them. When the sides of the blocks are equally illuminated, the two front faces are lighted up equally by diffusion from within.

JOLY STEAM CALORIMETER. A differential method of measuring **specific heats** of gases at constant volume, based upon the difference in amount of condensation of steam on an evacuated metal sphere and that on an identical sphere filled with the gas under investigation.

JORDAN COSMOLOGICAL THEORY. Theory that the total energy of the universe is zero, based on the observation that the rest energy and gravitational potential energy are of the same order of magnitude and of opposite sign. By equating large dimensionless ratios derived from astronomical and atomic observations, the theory leads to the conclusion that the **gravitational constant** is decreasing as A^{-1}, and the mass increasing as A^2, where A is the **age of the universe.**

JORDAN - WIGNER COMMUTATION RULES. Rules obtained for a quantized field theory by replacing the **commutators** in the canonical **commutation rules** by **anticommutators.** These rules lead to the **Pauli exclusion principle** and are applicable to **fermions.**

JOSHI EFFECT. An electric current through a gas or vapor is changed, i.e., increased or decreased, by irradiating the gas or vapor with light.

JOULE. A unit of energy or work in the **MKS system of units,** abbreviation J. The work done when a force of one **newton** produces a displacement of one meter in the direction of the force.

$$1\ J = 10^7 \text{ erg} = 0.2390 \text{ calorie.}$$

JOULE-CLAUSIUS VELOCITY. A quantity used in describing the kinetic behavior of gases, and defined by the equation $p = \frac{1}{3}dG^2$, where p is the pressure of the gas, d is the density, and G is the Joule-Clausius velocity.

JOULE CYCLE. A quantity of ideal gas is taken through the following reversible processes: (a) from a pressure P_2 and volume V, compressed adiabatically to pressure P_1; (b) heated at constant pressure P_1; (c) expanded adiabatically to pressure P_2; (d) cooled at constant pressure P_2 to initial volume V.

The efficiency of a Joule engine is

$$1 - \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}},$$

where γ is the ratio of the specific heats.

JOULE EFFECT. See discussion of **magnetostriction.**

JOULE EFFECT, INVERSE. See discussion of **magnetostriction.**

JOULE EXPERIMENT. Experiment designed to detect the presence of intermolecular attractions in a gas. The gas, contained in a small steel vessel, was allowed to expand into another vessel which was evacuated, thereby increasing the potential energy due to the intermolecular forces. This increase takes place at the expense of the kinetic energy of the molecules, the system being isolated, i.e., a temperature drop should occur. The original experiment failed to detect this drop owing to the large thermal capacity of the apparatus. The effect would be zero in the case of an ideal gas, where there are no intermolecular attractions. (See also **Joule-Thomson effect.**)

JOULE LAW. The quantity of heat generated by a steady electric current is proportional to the resistance of the conductor in which the heat is generated, to the square of the current, and to the time of its duration: $H = KRI^2t$. If the resistance is in ohms, the current in amperes, the time in seconds, and the heat in calories, the constant K has the value 0.2390 calories/joule

JOULE-ROWLAND METHOD FOR MECHANICAL EQUIVALENT OF HEAT. This is Joule's well-known method in which the mechanical energy of a paddle wheel is dissipated in a calorimeter filled with water. The original experiments of Joule yielded poor values for J, but were much improved by the modifications to his apparatus introduced by Rowland

JOULE-THOMSON COEFFICIENT. The ratio of the change in temperature to the change in pressure when a gas expands at constant **enthalpy** to a lower pressure through a small aperture or porous plug

JOULE-THOMSON EFFECT. In passing a gas at high pressure through a porous plug or small aperture, a difference of temperature between the compressed and released gas may be noticed Hydrogen and helium become warmer and all other gases cooler at ordinary temperatures and pressures. This phenomenon is called the Joule-Thomson effect. It is due to the departure of real gases from the **ideal gas laws.** With a perfect gas no difference should be observed.

JOULE-THOMSON INVERSION TEMPERATURE. The temperature, or one of the two possible temperatures, at which the **Joule-Thomson coefficient** changes its sign for a given gas.

JOURNAL. The region of surface contact between a rotating member and a fixed supporting member. Generally impregnated with some form of lubricant to reduce friction (See **bearing.**)

JUNCTION (IN A SEMICONDUCTOR DEVICE). A region of transition between **semiconducting regions** of different electrical properties. (See also **barrier layer.**)

JUNCTION (IN A WAVEGUIDE). A point or region in a **waveguide** at which provision is made for the flow of energy into two or more paths.

JUNCTION, ALLOY (IN A SEMICONDUCTOR). A junction formed by alloying one or more **impurities** to a **semiconductor** crystal.

JUNCTION, COLLECTOR (OF A SEMICONDUCTOR DEVICE). A **junction** normally biased in the high-resistance direction, the current through which can be controlled by the introduction of minority carriers. (See **carrier, minority.**)

JUNCTION, DIFFUSED (IN A SEMICONDUCTOR). A **junction** which has been formed by the diffusion of an **impurity** within a **semiconductor** crystal.

JUNCTION DIODE. See **diode, junction.**

JUNCTION, DOPED (IN A SEMICONDUCTOR). A **junction** produced by the addition of an **impurity** to the melt during crystal growth.

JUNCTION, *E*-PLANE TEE. For a rectangular uniconductor **waveguide,** a tee junction (see **junction, tee**) of which the electric field vector of the **dominant wave** of each arm is parallel to the plane of the longitudinal axes of the guides

JUNCTION, EMITTER (IN A SEMICONDUCTOR). A **junction** normally biased in the low-resistance direction to inject minority carriers (see **carrier, minority**) into an interelectrode region.

JUNCTION, FUSED (IN A SEMICONDUCTOR). A **junction** formed by recrystallization on a base crystal from a liquid phase of one or more components and the **semiconductor.**

JUNCTION, GROWN (IN A SEMICONDUCTOR). A **junction** produced during growth of a crystal from a melt.

JUNCTION, *H*-PLANE TEE. For a rectangular uniconductor waveguide, a tee junction (see **junction, tee**) of which the magnetic field vector of the **dominant wave** of each arm is parallel to the plane of the longitudinal axis of the guides.

JUNCTION, HYBRID. Waveguide arrangement with four branches which, when branches are properly terminated, has the property

that energy can be transferred from any one branch into only two of remaining three. In common usage, this energy is equally divided between the two branches.

JUNCTION, *N-N* (IN A SEMICONDUCTOR). A region of transition between two regions having different properties in n-type semiconducting material. (See **semiconductor, *n*-type.**)

JUNCTION, *P-N* (IN A SEMICONDUCTOR). A region of transition between p- and n-type semiconducting material. (See **semiconductor, *p*-type** and **semiconductor, *n*-type.**)

JUNCTION, *P-P* (IN A SEMICONDUCTOR). A region of transition between two regions having different properties in p-type semiconducting material. (See **semiconductor, *p*-type.**)

JUNCTION POINT. See **node.**

JUNCTION, RATE-GROWN (IN A SEMICONDUCTOR). A grown junction (see **junction, grown in a semiconductor**) produced by varying the rate of crystal growth.

JUNCTION, SERIES TEE. A tee junction (see **junction, tee**) having an equivalent circuit in which the impedance of the branch guide is predominantly in series with the impedance of the main guide at the junction.

JUNCTION, SHUNT TEE. A tee junction (see **junction, tee**) having an equivalent circuit in which the impedance of the branch guide is predominantly in parallel with the impedance of the main guide at the junction.

JUNCTION, TAPERED-RIDGE. A waveguide-coaxial line **junction** which uses a tapered section of ridge waveguide to widen the band over which low standing wave ratios may be obtained. (See **waveguide, ridge.**)

JUNCTION, TEE. A junction of **waveguides** in which the longitudinal guide **axes** form a T. The guide which continues through the junction is the main guide; the guide which terminates at a junction is the branch guide.

JUNCTION, Y (OR WYE). A junction of **waveguides** such that the longitudinal guide axes form a Y.

JURIN LAW. The height of rise of a liquid in a capillary tube of internal radius a is

$$h = \frac{2\gamma \cos \alpha}{\rho g a}$$

where γ is the surface tension of the liquid, α is the angle of contact with the **capillary**, ρ is the liquid density.

JUST SCALE. See **scale, just.**

K

K. (1) Proportionality constant in force-mass equation (K). (2) Torsion constant, or torque per unit twist (k). (3) Unit vector in Z-direction (**k**). (4) Miller index (h,k,l). (5) Degree Kelvin (°K). (6) Reaction velocity constant (k). (7) Luminous efficiency (K); monochromatic luminous efficiency (K_λ). (8) Magnetic volume susceptibility (k). (9) Mass transfer coefficient (K or k). (10) Thermal conductivity (k). (11) Compressibility factor (k). (12) Equilibrium constant (K). (13) Boltzmann constant (k). (14) Curvature (K). (15) Force constant (k). (16) Radius of gyration (k). (17) Kerr constant (K). (18) Spring constant (k). (19) Grid conductance, at 0 frequency and constant plate potential (k_g) (20) Potassium (K). (21) Proportionality constant in Coulomb's law (K_e). (2) Proportionality constant in law of attraction between currents (K_m). (23) Kayser, proposed unit of wave number cm^{-1} (K). (24) Absolute value of vibronic angular momentum of polyatomic molecule (K, used in case where electron is zero or loosely-coupled). (25) Circuit-diagram designation for cathode of vacuum-tube (k). (26) Reproduction factor, nuclear process (k).

K-CAPTURE. See **K-electron capture.**

K-ELECTRON. An electron having an orbit of such dimensions that the electron constitutes part of the first shell of electrons surrounding the atomic nucleus; orbitals in the K-shell are characterized by the **principal quantum number** value of unity, i.e., it is the innermost shell.

K-ELECTRON CAPTURE. Capture by a nucleus of an electron of the "K" shell, or the innermost shell of electrons surrounding the nucleus. This process accompanies the decay processes of artificially-radioactive atomic nuclei, notably those emitting **positrons.**

K/L RATIO The ratio of the number of internal conversion electrons from the K-shell to the number of internal conversion electrons from the L-shell, emitted in the de-excitation of a nucleus. This is equal to α_K/α_L where α_K is the K-electron conversion ratio, and α_L the L-electron **conversion ratio.**

K-LINE. (1) One of the characteristic lines in the **x-ray spectrum** of an atom produced by K-electron excitation. (2) The designation used for a strong line in the **emission spectrum** of calcium, useful in fixing spectrographic positions.

KRS-5 (KRYSTALL, SYNTHETISCH NO. 5). An eutectic mixture of thallium bromide and thallium iodide. KRS-5 is transparent to the infrared radiation extending from the red end of the visible to past 30 microns. It is rather soft and difficult to polish, but is used for infrared windows, lenses and even prisms, because of its remarkable range of transparency.

K-RADIATION. The radiation, or rather radiations, emitted when **K-electrons** are excited. These radiations are **x-rays** of relatively high frequency, and of similar spectral distribution for the various elements, except that they are displaced in the direction of decreasing wavelength as the **atomic number** of the element increases. They are commonly obtained by bombardment with high-speed electrons of the particular element, usually in the form of the metal.

K-SHELL. The innermost shell of electrons surrounding the atomic nucleus; this shell consisting of the **K-electrons.**

k-SPACE. An abbreviation for **momentum space,** or **wave-vector** space, i.e., the space mapped out by the **wave-vectors k,** e.g., of the various electronic **wave functions** in a metallic crystal. It has the same symmetry properties as the **reciprocal lattice** of the crystal.

KALUZA THEORY. Unified field theory of gravitation and electromagnetism based on a five-dimensional continuum, the fields being independent of the fifth coordinate in a special

coordinate system. Momentum of a particle in the fifth direction is interpreted physically as the electric charge of the particle.

KAMPOMETER. An instrument used to measure **radiant energy,** especially in the thermal region.

KAPNOMETER. An apparatus used to determine the concentration of solid or liquid particles dispersed in a gas, such as the density of smoke or fog.

KARMAN CONSTANT. An absolute constant introduced by von Karman in his similarity theory of turbulence. In turbulent boundary layers sufficiently close to the boundary, the rate of shear $\partial U/\partial y$ is related to distance from the boundary y by

$$\frac{\partial U}{\partial y} = \left(\frac{r_0}{p}\right)^{1/2} \frac{1}{Ky}$$

where r_0 is the shear stress at the wall, p is the fluid density, K is the Karman constant. The best available value of K is 0.41 ± 0.01.

KARMAN STREET OF VORTICES. Beyond a critical flow **Reynolds number,** the laminar wake of a long cylinder is unstable and develops into a double row of diffuse vortices, arranged alternately in two rows as are street-lamps. T. von Karman investigated the stability of a double row of line vortices in an inviscid fluid, and showed that only one alternating arrangement is stable, and that the computed ratio of spacing of the vortices to separation of the rows agrees well with observation.

KATABATIC WIND. Cold-air drainage downhill toward lower terrain. In desert ravines katabatic winds locally reach high velocities.

KATHAROMETER. An instrument for determining the composition of a gas mixture by measuring variations in its **thermal conductivity.**

KATOPTRIC SYSTEM. If an optical system is **convergent,** it is called katoptric if the object space **focal length** is positive and the image space focal length is negative. If a lens system is **divergent,** it is called katoptric if the object space focal length is negative and the image space focal length is positive.

KAYSER. A unit of **wave number,** the reciprocal centimeter (cm^{-1}).

KEEP-ALIVE ANODE. A **holding** or **excitation anode.**

KEESOM RELATIONSHIP. A relationship between molecular attraction and the interaction of **dipoles.** The resultant attraction depending on the relative orientation of the dipoles of the molecules may be expressed in terms of the mean interaction potential energy U_0 between two polar molecules

$$U_0 = \frac{-2\mu^4}{3r^6kT}$$

where μ is the dipole moment, r, the distance between the molecules, k, the **Boltzmann constant,** and T, the absolute temperature.

KELLNER EYEPIECE. A **Ramsden eyepiece** in which the eye lens is an achromatized, cemented doublet.

KELLOGG EQUATION. An **equation of state,** relating the pressure, absolute temperature, and density of a gas. It is of the form:

$$p = RT\rho + \left(B_oRT - A_o - \frac{C_o}{T^2}\right)\rho^2 + \left(bRT - a - \frac{c}{T^2}\right)\rho^3$$

in which p is the pressure, T the absolute temperature, ρ the density, R the **gas constant,** and A_o, B_o, C_o, a, b, and c are constants.

KELVIN ASTATIC GALVANOMETER. See **galvanometer. Kelvin astatic.**

KELVIN CIRCULATION THEOREM. In any motion of an inviscid, **barotropic fluid,** the circulation around a path moving with the fluid is invariant.

KELVIN DOUBLE BRIDGE. See **bridge, Kelvin double.**

KELVIN EFFECT. See **thermoelectric phenomena.**

KELVIN ELECTROMETER. See **electrometer, Kelvin.**

KELVIN EQUATION FOR SURFACE TENSION.

$$U_s = \gamma - T\frac{d\gamma}{dT}$$

where U_s is the surface energy per unit area, γ is the **surface tension,** T is absolute temperature.

KELVIN LAW. When a system of rigid circuits does mechanical work under constant current conditions, the energy of the circuits increases at the same rate as work is done. (See **force on rigid circuits; force on a system of conductors.**)

KELVIN METHOD OF MEASURING GALVANOMETER RESISTANCE. In a Wheatstone bridge (see **bridge, Wheatstone**) at balance, shorting the "detector" branch has no effect. Hence, if a **galvanometer** is used as one bridge-arm, and a shorting-switch as the "detector," balance of the bridge will yield the resistance of the galvanometer.

KELVIN TEMPERATURE SCALE. See **temperature scale, Kelvin.**

KELVIN-VARLEY SLIDE. An arrangement often used in **potentiometers,** wherein a vernier **voltage-divider** is moved as a unit along a coarse divider, maintaining a constant net divider resistance for all settings.

KENDALL EQUATION FOR VISCOSITY. For solutions of non-electrolytes

$$\eta^{1/3} = x_1\eta_1{}^{1/3} + x_2\eta_2{}^{1/3}$$

for a binary mixture, where x and η are mole fraction and **viscosity** respectively.

KENNEDY-THORNDIKE EXPERIMENT. Modified form (1932) of the **Michelson-Morley experiment** in which the path lengths of the split beam were made unequal. The **Fitzgerald-Lorentz contraction hypothesis** would then be unable to explain the null result.

KENNELLY-HEAVISIDE LAYER. A region of the atmosphere, usually taken as identical with the **ionosphere.**

KENOPLIOTRON. A diode-triode **vacuum tube** in which the cathode of the triode element is the anode of the diode element.

KENOTRON. A high-vacuum diode rectifier **tube.** The tube contains a hot **cathode,** either filament or indirectly heated type, and an **anode.** Since electrons are emitted by the cathode and may be drawn to the anode when the latter is positive but the reverse process cannot take place, the tube will pass current in only one direction, hence serves as a rectifier.

KEPLER, LAWS OF. See **laws of Kepler.**

KERNEL. A known function, also called a **nucleus,** $K(x,z)$ which occurs in an **integral equation.** It is **symmetric** if $K(x,z) = K(z,x)$; **Hermitian** if $K(x,z) = K^*(z,x)$; **skew Hermitian** if $K(x,z) = -K^*(z,x)$, where the asterisk indicates the **complex conjugate.** A **polar** kernel has the form $K(x,z) = u(z)G(x,z)$, where $G(x,z)$ is symmetric. It may be transformed into a symmetric kernel by a change of the dependent variable. A **definite** kernel, positive or negative, satisfies the requirement

$$\int f(x)dx \int K(x,z)f(z)dz \gtrless 0,$$

where $f(x)$ is any finite function defined over the range for which the kernel is defined. A **singular kernel** has a discontinuity, one or more singular points within its integration limits, or an infinite integration limit. A **solving kernel** or **resolvent** is an infinite series of **iterated** kernels which appears in the **Liouville-Neumann series.**

KERNEL, DIFFUSION. The total flux at a point resulting from a distribution of sources throughout space is given by

$$\phi(\mathbf{r}_0) = \int_{\text{all space}} S(\mathbf{r}_0)G(\mathbf{r}_0,\mathbf{r})d\mathbf{r}_0.$$

In this expression the term $G(\mathbf{r}_0,\mathbf{r})$ is called the kernel, and its form depends on the geometry. $S(\mathbf{r}_0)$ is the source strength at the point $\mathbf{r}_0$. The common kernels are the point, plane, line, spherical shell, and cylindrical shell.

KERNEL, GAUSSIAN (FERMI AGE). See **kernel, slowing down.**

KERNEL, GROUP-DIFFUSION. An approach to the problem of determining the spatial distribution of the slowing down density of neutrons in an infinite medium, as a function of energy, in which it is postulated that the energy of the neutrons is divided into a finite set of groups. (See **group diffusion method.**)

KERNEL, SLOWING DOWN. A generalization of diffusion kernels (see **kernel, diffusion**) in which the slowing-down density from a distributed source is expressed in terms of

slowing-down kernels, which represent the probability that a neutron will go from one position to another while slowing down through a specified energy range.

KERR CELL. A cell with electrodes which can hold a suitable dielectric fluid for observing the Kerr effect. By placing such a cell between crossed **nicols,** a pulse of light of very short duration may be passed by applying a potential difference to the electrodes for a very short time.

KERR EFFECT. Many isotropic substances when placed in an electric field behave like a uniaxial crystal (see **crystal, uniaxial**) with the optic axis in the direction of the field. If n is the index of the substance in the absence of the field and n_p and n_s are the indices for the magnetic vector parallel and perpendicular to the field, it is shown that $n_p - n_s = \lambda KE^2$, Kerr law, where K is the Kerr constant and E is the electric field strength. The relation $n_p - n = 2(n_s - n)$ is the Havelock law.

KET VECTOR. Vector in **Hilbert space** describing the state of a dynamical system in **quantum mechanics.** Denoted by the symbol $|A\rangle$.

KEV. Symbol for 1000 electron volts, a unit of energy.

KEY. A hand-operated switch used for signaling purposes.

KEY CLICK. The sharp transient heard in **loudspeakers** or **headphones** when a **key** is open or closed.

KEY-CLICK FILTER. See **click filter.**

KEYER. A device which changes the output of a **transmitter** from one value of amplitude or frequency to another, in accordance with the intelligence to be transmitted. This applies generally to telegraphic keying.

KEYES EQUATION. An **equation of state** for a gas, deduced from the concept of the nuclear atom. This equation is designed to correct the **van der Waals equation** for the effect upon the term b of the surrounding molecules. The equation is written as

$$P = \frac{RT}{V - Be^{-\alpha/V}} - \frac{A}{(V + l)^2}$$

in which P is pressure, T is absolute temperature, V is volume, R is the **gas constant,** e is the base of natural logarithms, 2.718···, and A, α, B, and l are constants for each gas.

KEYING. The forming of signals, such as those employed in telegraph transmission, by an abrupt modulation of the output of a direct-current or an alternating current source as, for example, by interrupting it or by suddenly changing its amplitude, or frequency or some other characteristic.

KEYING, BACK-SHUNT. A method of **keying** a **transmitter** in which the radio-frequency energy is fed to the antenna when the telegraph key is closed, and to an **artificial load,** when the key is open

KEYING, BREAK-IN. A method of operating a radiotelegraph communication system in which the receiver is capable of receiving signals during transmission **spacing intervals.**

KEYING CHIRP. A **key click.**

KEYING, ELECTRONIC. A method of **keying** whereby the control is accomplished solely by electronic means.

KEYING, PLATE. **Keying** effected by interrupting the plate-supply circuit.

KEYING, SINGLE-TONE. That form of **keying** in which the **modulating wave** causes the **carrier** to be modulated with a single tone for one condition, which may be either "marking" or "spacing," and the carrier is unmodulated for the other conditions.

KEYING, TWO-SOURCE FREQUENCY. That form of **keying** in which the **modulating wave** abruptly shifts the output frequency between predetermined values, where the values of output frequency are derived from independent sources and, therefore, the output wave is not coherent and, in general, will have a phase discontinuity.

KEYING, TWO-TONE. That form of **keying** in which the **modulating wave** causes the carrier to be modulated with a single tone for the "marking" condition and modulated with a different single tone for the "spacing" condition

KEYSTONE DISTORTION. See **distortion, keystone.**

KICK SORTER. A British and Canadian term for **pulse-height analyzer.**

KICKBACK. See **flyback.**

KICKBACK SUPPLY. See **flyback supply.**

KIKUCHI LINES. A series of spectral lines obtained by directing an **electron** stream against the surface of a **crystal,** due to the **scattering** of electrons by layers of atoms in the crystal structure.

KILO-. A prefix used with many physical units, denoting one thousand. Thus 1 kilometer = 1000 meters; 1 kilowatt = 1000 watts.

KILOCALORIE. Unit of energy, abbreviation Kcal or Cal. One thousand **calories.** The energy required to raise one kilogram of water through a temperature rise of one degree Celsius, without any vaporization. When greater precision is needed, the kilocalorie is defined as 1.1840 joules.

KILOCURIE. One thousand **curies.**

KILOGRAM. (1) Unit of mass, abbreviation K or Kg. A mass equal to that of the International prototype kilogram, a platinum body kept at Sevre.

(2) Unit of force The weight of one kilogram mass. When extreme precision is needed, it is specified that this weight shall be measured at a point on the earth's surface where the acceleration due to gravity is exactly 9.80665 meters/sec^2.

KILOGRAM METER. A unit of **work** in the gravitational system defined as the work done in raising a mass of one **kilogram** through a distance of one **meter** against gravity. It equals 98,066,500 ergs.

KILOJOULE. One thousand **joules.**

KILOLITER. One thousand **liters.**

KILOMETER. One thousand **meters.**

KILOWATT. A unit of **power**—defined as 1000 **watts**—which ordinarily serves as the commercial measure for electrical power. Electrical power of one kilowatt used steadily for one hour involves an energy consumption of one kilowatt-hour. A kilowatt is equal to about 1.34 hp.

KILOWATT HOUR. A commercial unit of energy equal to 1000 **watthours** or 3,600,000 **joules.**

KINEMATIC VISCOSITY. See **viscosity, kinematic.**

KINEMATICAL RELATIVITY. Relativity theory developed by Milne and based fundamentally on the equivalence of observers who are receding from each other with constant velocity. Thus related directly to the **expanding universe,** the Hubble law being a postulate of the theory. A kinematic time t and a dynamic time τ are introduced, the age of the universe being finite in t-time and infinite in τ-time. On τ-time, dimensions are constant, there is no expansion, but atomic frequencies increase. One criticism of the theory is that the first and last of these are not consistent.

KINEMATICS. The geometry of abstract motion, without regard to forces or bodies of matter. Two aspects need special consideration: the motion of points and the motion of rigid figures. Whatever system of space coordinates is found simplest may be used, and may be transformed from one system to another as desired.

The motion of a point is completely specified by giving each of its three rectangular coordinates (for example) as a function of the time; that is, by writing its "equations of motion":

$$\left.\begin{aligned} x &= f_1(t), \\ y &= f_2(t), \\ z &= f_3(t). \end{aligned}\right\} \tag{1}$$

In many cases the information represented by these equations is supplied only indirectly in the statement of a problem. For example, an expression may be given for the component of the linear **velocity** or the linear **acceleration,** as a function of either the time or the distance. In such cases a differential equation is first obtained. Thus if it is specified that the X-component of the acceleration is constant and equal to a, the differential equation is

$$\frac{d^2x}{dt^2} = a; \tag{2}$$

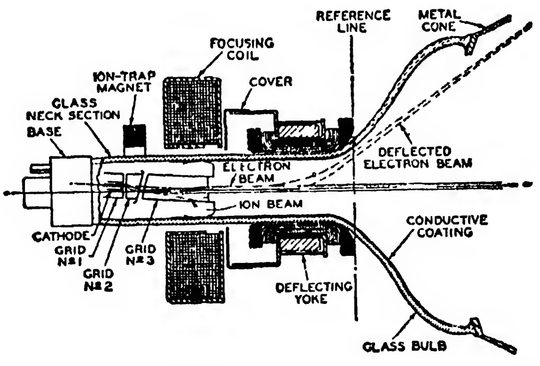
and the corresponding equation of (uniformly accelerated) motion is its solution,

$$x = \tfrac{1}{2}at^2 + v_0t + x_0, \qquad (3)$$

in which the integration constants x_0, v_0, stand respectively for the initial distance (value of x when $t = 0$) and the initial velocity. By eliminating t from the equations of motion (1) three geometric equations may be arrived at, one in x, y, one in x, z, and one in y, z, any two of which determine the path of the moving point in space

In discussing the kinematics of rigid bodies, the motion of some point in the body may be specified by a set of equations similar to (1), but one must also introduce a set of equations expressing the orientation of the body relative to a set of coordinate axes having this point as an origin and undergoing translation without rotation. (See **Euler angle; Rectilinear Motion of a Particle.**)

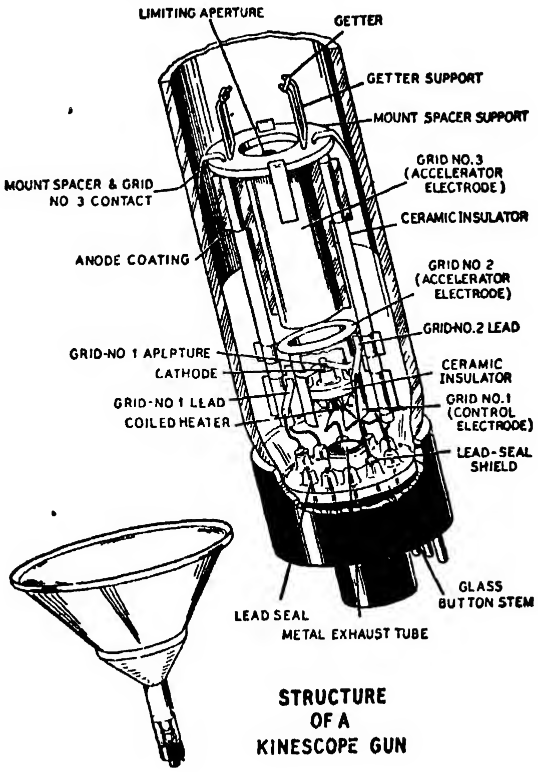
KINESCOPE. This is a **cathode ray tube** used as the picture tube in a **television** receiver. The signal representing the picture intensity is fed to the **grid** of the electron gun so the intensity of the beam varies with the intensity of the original scene. This variable



Kinescope

beam is swept back and forth, up and down by deflecting voltages impressed on the deflecting plates and synchronized with the scanning of the camera tube (see **iconoscope** and **image dissector**). The beam of electrons then hits the fluorescent end screen of the tube and reproduces the scene being televised. (See **picture tube.**)

KINESCOPE GUN. The **electron gun** for a kinescope or picture tube.



Cutaway drawing of the electron gun structure used in a kinescope CRO tube (Courtesy of Radio Corporation of America)

KINETIC MOMENTUM. Kinetic momentum of a charged particle in an electromagnetic field $\mathbf{A}$, ϕ, the vector $\mathbf{p} - (e/c)\mathbf{A}$, where $\mathbf{p}$ is the momentum. Name arises from analogy with the kinetic energy $W - e\phi$, where W is the total energy.

KINETIC POTENTIAL. See **Lagrangian function.**

KINETIC REACTION. The product of mass and acceleration.

KINETIC THEORY. A theory (proved by direct experiment) which explains the phenomena of heat as due to the kinetic motion and elastic collisions of atoms and molecules.

"KINETIC-THEORY" ELASTICITY OF LIQUID. Part of the total elasticity of a liquid can be thought of as the change in stress, caused by a given deformation, arising from increased interaction between molecules as a result of their thermal motion, distinct from change of stress due to distortion of the **lattice structure.** This first part is the "kinetic theory" elasticity.

KINETICS. (1) The branch of physics which deals with the effect of forces or of torques upon the motions of material bodies. The basis of this subject, so far as the classical theory is concerned, consists in the **Newton laws of dynamics,** which may be extended to include the **d'Alembert principle** of kinetic equilibrium. The motions of a particle or of a rigid body may be either "free" or "constrained"; that is, it may be at liberty to move in any manner in obedience to the applied forces or torques, or there may be present material barriers which limit its linear motion to a certain path or surface, or its rotation to a certain axis. (2) In chemistry, the study of time-dependence of chemical reactions.

KIPP RELAY. A form of **bistable multivibrator** or **trigger circuit.**

KIRCHHOFF FORMULA FOR VAPOR PRESSURE. See **vapor pressure, Kirchhoff formula for.**

KIRCHHOFF LAWS OF NETWORKS. Two laws relating to electric networks carrying steady currents. The general case is that of n points or junctions, each one of which is connected with each of the $n - 1$ remaining points by a conductor containing a source of electromotive force. Kirchhoff's two statements are as follows:

(1) If conductors forming part of a network carrying a steady current meet at one point, the sum of the currents flowing toward the point is equal to the sum of those flowing away from it; or the algebraic sum of all the currents in these conductors is zero.

(2) Starting at any one of the junctions of such a network and following any succession of the conductors which form a closed path, around either way to the starting point, the algebraic sum of the products formed by multiplying the resistance of each conductor by the current through it is equal to the algebraic sum of the electromotive forces encountered on the journey. (In this reckoning, we call all currents moving with us positive, and all electromotive forces tending to cause such currents positive.)

Maxwell has set forth a general method of calculating the currents and the relative potentials of the junctions when the resistances and electromotive forces in the several branches of a network are given. For a network of n points, this method involves the solution of $n - 1$ simultaneous, first-degree equations. The work is often simplified, however, by the circumstance that some of the conductors or some of the electromotive forces are absent.

KIRCHHOFF RADIATION LAW. The ratio between the **absorptivity** and **emissive power** is the same for each kind of rays for all bodies at the same temperature, and is equal to the emissive power of a **black body** at that same temperature.

KIRKENDALL EFFECT. When markers are placed at the interface between an alloy (CuZn) and a metal (Cu), and the whole heated to a temperature where **diffusion** is possible, the markers move towards the alloy region. This is explained by assuming that the zinc diffuses more rapidly than the copper, and thus diffuses out of the alloy. Such a process is impossible if the diffusion is by direct exchange of atoms.

KIRKWOOD APPROXIMATION. An approximation used in the kinetic theory of liquids. The force on one molecule of a set of molecules is assumed to be the sum of the forces exerted, neglecting in turn all but one other molecule of the set. In this way an equation may be obtained for the radial distribution function.

KLEIN-GORDON EQUATION. The equation

$$\left(\frac{\partial}{\partial x_\mu} - \frac{ie}{\hbar c} A_\mu\right)\left(\frac{\partial}{\partial x_\mu} - \frac{ie}{\hbar c} A_\mu\right)\psi = \left(\frac{mc}{\hbar}\right)^2 \psi,$$

to describe the motion of a spinless particle of charge e, rest-mass m (for example, a $\pi^\pm$ meson) in an electromagnetic field described by the potentials A_μ.

KLEIN-NISHINA FORMULA. (1) Expression derived from the **Dirac electron theory** without **radiative corrections** for the differential cross section for scattering by an electron at rest of a quantum with momentum $\mathbf{k}_0$ to give a quantum with momentum $\mathbf{k}$ in the element of solid angle $d\Omega$:

$$d\phi = \frac{r_0^2}{4} d\Omega \frac{k^2}{k_0^2}\left(\frac{k_0}{k} + \frac{k}{k_0} - 2 + 4\cos^2\Theta\right)$$

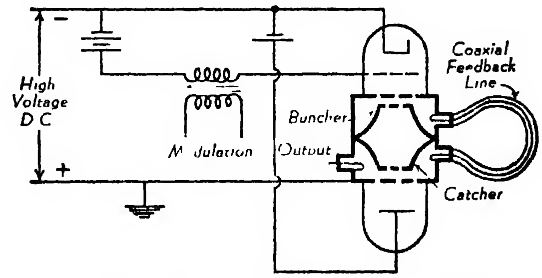
(Θ = angle between directions of **polarization** of $\mathbf{k}$ and $\mathbf{k}_0$).

(2) The integral Klein-Nishina formula gives the total cross section for scattering, not being restricted to a solid angle.

KLEIN PARADOX. Consequence of the **Dirac electron theory** that a particle could penetrate a potential barrier of greater than 1 mev by making a transition from a positive energy state to a negative energy state. The transition probability is small, however, unless such a potential change occurs over a distance of the order of the electron **Compton wavelength.**

KLEIN-RYDBERG METHOD. For constructing the potential energy curve of a diatomic molecule (e.g., H_2) point by point from observed vibrational and rotational levels without assuming an analytical expression for the potential function. For an analytical formulation of this method, see A. L. G. Rees, *Proc. Phys. Soc.*, London, **59**, 1008 (1947).

KLYSTRON. An electron **tube** of the velocity-modulated type used in **ultra high frequency** circuits. At these extremely high frequencies (measured in terms of some tens of thousands of megacycles) the conventional **vacuum tubes** become useless because of lead and electrode inductance and capacitance, and transit-time effects, so a radically different approach is necessary. The klystron is one solution of the problem. This vacuum tube consists of a **cathode, grid** and perforated **anode** somewhat like the electron gun of the **cathode ray tube** (however, here the electrodes are grid-like structures rather than the cap with a single hole) followed by two **cavity resonators** separated a calculated distance and finally a collector. All electrodes except the collector have grid-like surfaces so the electrons can pass on through them. The beam of random-velocity electrons passing through the grid is accelerated by the positive potential applied to the first resonant cavity structure, causing this structure to serve as an anode. These electrons pass through the grids into the cavity which is called the buncher. Here the standing waves in the cavity act on the electrons and cause them to change speed so they arrive at the second cavity, called the catcher, in bunches (having passed out of the first into a field free space and then into the second through the grids in the sides of the cavities). Here the energy of the electrons is absorbed by the field and contributes to the useful output and normally supplies also the driving energy for the buncher. The electrons then pass on to the collector and return to the



Modulated two-cavity klystron oscillator

cathode. By proper adjustment of the voltages and spacings of the cavities the circuit may be made to oscillate or amplify as desired. A circuit of a modulated two-cavity klystron oscillator is shown.

KLYSTRON, ADMITTANCE-COMPRESSION FACTOR. The approximate ratio in which the **transadmittance** of a two-cavity **klystron** is reduced from its small-signal value as the **bunching parameter** is increased.

KLYSTRON AMPLIFIER (TWO-CAVITY). See **klystron.**

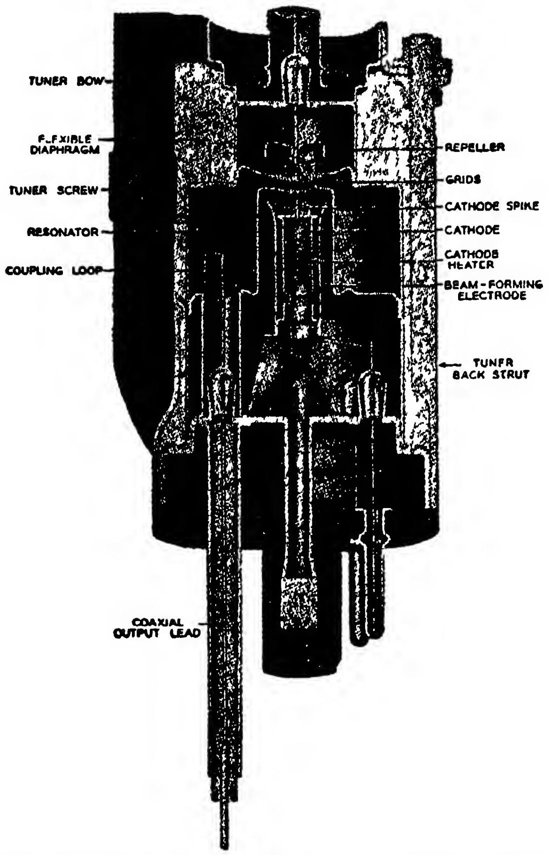
KLYSTRON, CASCADE-AMPLIFIER. A **klystron** which contains three resonant cavities for increased power amplification and output. The third resonator lies between the input and output resonators and has no external connection. It is excited by the bunched beam that emerges from the input-resonator gap, and it produces further bunching of the beam.

KLYSTRON(S), DEPTH OF MODULATION IN. The ratio, which determines the change of electron velocity in the input gap, of the product of the beam-coupling coefficient, multiplied by the alternating component of **gap voltage** in the first resonator, divided by the d-c accelerating voltage between the cathode and the first gap.

KLYSTRON FREQUENCY MULTIPLIER. A two-cavity **klystron** in which the output cavity, driven by the harmonic-rich **beam** current, is tuned to some derived **multiple of** the **fundamental frequency.**

KLYSTRON OSCILLATOR. A **klystron** in which regenerative coupling between output cavities causes sustained oscillations.

KLYSTRON, REFLEX. A single-cavity **klystron.** As in the two-cavity klystron, electrons are accelerated in the direct field between the cathode and the cavity resonator. After passing through the cavity resonator, where they are given changes in velocity, they are brought to rest and returned to the cavity



Type 2K29 Fig 10-cm reflex klystron (Courtesy Bell System Technical Journal)

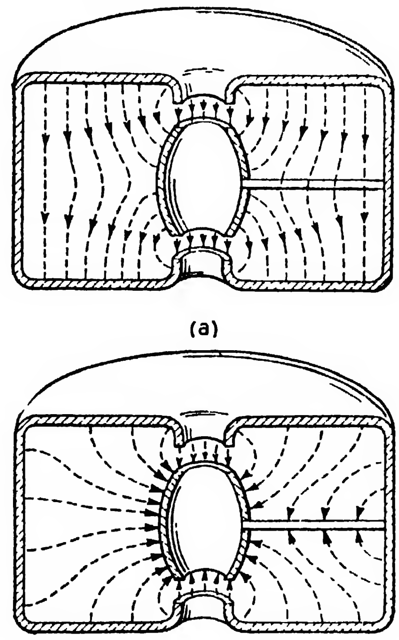
by means of a negative electrode called the repeller. Those electrons which make this first transit through the cavity during the half of the cycle in which they are accelerated by the alternating field emerge with increased velocity. Those which make their first transit during the following half-cycle are retarded, and emerge with decreased velocity. The electrons with the higher velocities approach closer to the repeller than those with the smaller velocities, and hence take a longer time to return to the resonator. Since they left earlier, however, they may arrive at about the same time as those with smaller velocities. By proper adjustment of the repeller voltage relative to accelerating voltage, the electrons can be made to return to the resonator in bunches at an instant in the cycle of alternating resonator field such that they are retarded by the resonator field They therefore deliver energy to the cavity resonator. If the power delivered to the resonator exceeds the losses in the resonator and circuits coupled to it, sustained oscillations may take place.

KLYSTRON REPELLER. The negative electrode in a reflex klystron (see **klystron, reflex**) which forces the electron beam to pass through the resonator a second time.

KLYSTRON, TWO-CAVITY. A **klystron** having two resonant cavities.

KLYSTRON, TWO-CAVITY, APPLEGATE DIAGRAM FOR. See **Applegate diagram (two-cavity klystrons).**

KLYSTRON, TWO-GAP, SINGLE-RESONATOR. A klystron, useful as an oscillator, which has one resonator instead of two in order to simplify the tuning procedure Where the two-gap resonator shown below is



Two-gap klystron resonator (By permission from "Microwave Theory and Techniques" by Reich et al., Copyright 1953, D. Van Nostrand Co., Inc.)

in resonance, in the indicated mode, the gap voltages are in phase and the transit angle must be $n + \frac{1}{4}$ where n is any integer.

KNOCKED-ON-ATOM. An atom of a solid which recoils after collision with an energetic particle such as a neutron, fission fragment, ion or atom moving through the solid. The knocked-on-atom may be displaced from its **lattice position** and may possess sufficient energy to displace other atoms.

KNUDSEN ABSOLUTE MANOMETER. Instrument for absolute measurement of very low pressures up to about 5 dyne cm^{-2}. At higher pressures, the manometer is not absolute, but must be calibrated against some other absolute instrument. The principle of operation is to measure the repulsion exerted between two plates a short distance apart in the gas, when a small temperature difference is maintained between them.

KNUDSEN COSINE LAW. It can be shown from kinetic theory that for a gas at rest at a uniform temperature, the number of molecules striking or leaving an area dS of the wall in a solid angle $d\omega$ making an angle θ with the normal is given by

$$\frac{dS}{4\pi} n\bar{c} \cos\theta d\omega,$$

where n is the number of molecules per cm^3, and $\bar{c}$ the mean velocity. This is known as the cosine law. Knudsen assumes that it holds for each molecule individually, that the direction of a molecule on leaving the wall is independent of its direction before striking, and that the law gives the probability of a molecule leaving the wall in a given direction. The laws are probably true for irregular surfaces, but do not hold in such cases as that of the diffraction of molecules from crystal lattices, which have a regular arrangement.

KNUDSEN FLOW. (Also known as free molecule diffusion). Flow of a gas through a long tube at pressures such that the **mean free path** is much greater than the tube radius.

KNUDSEN FORMULA FOR GAS FLOW. The formula for the quantity of gas passing any point (along a tube) per second in terms of the pressure gradient along the tube, the diameter, and the density of the gas at unit pressure and at the prevailing temperature is:

$$q = \frac{\sqrt{2\pi}}{6} \cdot \frac{d^3(p_1 - p_2)}{l\sqrt{\rho}}$$

where d is the internal diameter of the tube, $(p_1 - p_2)/l$ the pressure gradient, and ρ the density at unit pressure and the prevailing temperature.

KNUDSEN METHOD FOR VAPOR PRESSURE OF METALS. The method consists in measuring the rate of **effusion** of the vapor through a small aperture. The metal is contained in a silica pot with an aperture of known dimensions, and kept at an accurately-constant temperature. The silica pot is at the bottom of a long tube which is highly evacuated, and the vapor molecules stream through the aperture, condensing on the cool upper parts of the tube. From the rate of loss of weight the vapor pressure can be calculated. Vapor pressures of the order of 10 mm of mercury have been measured in this way.

KOCH RESISTANCE. The resistance produced by an illuminated, vacuum **phototube.**

KOHLRAUSCH, LAW OF. The **conductivity** of a neutral salt in dilute solution is the sum of two values, one of which depends upon the **cation,** the other upon the **anion.** In other words, each ion contributes a definite amount to the total conductance of the electrolyte, independent of the nature of the other ion.

KONEL METAL. An alloy of nickel, cobalt, iron, and titanium frequently employed as the base material for an indirectly-heated **cathode.**

KONOWALOFF RULE. An empirical conclusion reached by Konowaloff independently of the fundamental theoretical deductions of physical chemistry. It states that the vapor over a liquid system is relatively richer in the **component** whose addition to the liquid mixture results in an increase of the total **vapor pressure.**

KOPP LAW. The **molar heat** of a solid compound is equal approximately to the sum of the **atomic heats** of its constituents.

KOSSEL-SOMMERFELD DISPLACEMENT LAW. The arc spectrum (normal atom spectrum) of an element is similar, especially as regards **multiplet structure**, to first spark spectrum (singly-ionized atom spectrum) of the element one place higher in the periodic table, to the second spark spectrum (doubly-ionized atom spectrum) of the element two places higher, etc.

KOSTINSKY EFFECT. A photographic effect discovered by the Russian, Kostinsky (1906). It was found that if two areas of high density, e.g., star images, are close together, the restraining by-products formed in the process of development retard the development of the adjacent portions of the images so that the distance separating the two images is greater than is actually the case.

KOVAR. An alloy of nickel, cobalt and iron used extensively for metal-to-glass seals, because its temperature coefficient of expansion matches that of many types of glass over wide temperature ranges.

KRAMERS-KRONIG DISPERSION FORMULA. Relation between the real and imaginary parts of the refractive index of electromagnetic waves in passing through matter, arising from the fact that a signal cannot be propagated with a velocity greater than that of light *in vacuo*.

KROMAYER LAMP. See **lamp, Kromayer.**

KRONECKER DELTA. A **discontinuous** factor, usually designated by δ_{ij}, which is taken to be unity when $i = j$ and otherwise zero. It is a mixed **tensor** of second rank.

KRONIG-PENNEY MODEL. A one-dimensional periodic potential for which the wave equation may be solved exactly, and shows **band structure**, thus providing a mathematical model in which certain properties of metals may be verified by rigorous calculations.

KRYPTON. Gaseous element. Symbol Kr. Atomic number 36.

KUNDT CONSTANT. The **Verdet constant** divided by the **magnetic susceptibility.** In the case of ferromagnetic substances having variable susceptibility, the Verdet factor is not constant, but is proportional to the **susceptibility.** For such substances the Kundt factor has a constant value.

KUNDT EFFECT. The rotation of the plane of **polarized light** by certain liquids and gases when they are placed in a **magnetic field.**

KUNDT METHOD. A method of measuring the velocity of sound by means of longitudinal vibrations set up in a metal rod placed so as to develop stationary waves in air or other gas within a glass tube. A light powder, spread over the interior of the tube, is lumped together at the nodal points.

KUNDT RULE. When the **refractive index** of a solution increases, because of changes in composition or other causes, its **optical absorption bands** are displaced toward the red.

KUNDT TUBE. A glass tube used in the **Kundt method** for the velocity of sound.

KURIE PLOT. A graph of the **β-particle spectrum** in which the Fermi probability equation is rearranged in the form:

$$K(N/f)^{1/2} = C - (E + 1)$$

where N is the number of β-particles of momentum (or energy) lying within a certain narrow range, f is a complex function of the corresponding β-particle energy E as worked out by Fermi, and K and C are constants. The plot of $(N/f)^{1/2}$ against $(E + 1)$, often called a Kurie plot, is generally a straight line for allowed transitions and some **forbidden transitions**, in other words, the equation holds; and is used in determining the character of the β-transition and the maximum energy.

L

L. (1) Relative heat constant (L). (2) Latent heat per unit mass (l). (3) Levorotatory (l-). (4) Length (l or L). (5) Rest length (l_0). (6) Lorentz unit (L). (7) Miller index (h, k, l). (8) Direction cosine (l, m, n). (9) Free path or mean free path (l or λ). (10) Tait free path (l_T or λ_T). (11) Length of heat flow path (L or l). (12) Lagrange function (L). (13) Inductance (L). (14) Mutual inductance (L_{12}). (15) Azimuthal or orbital quantum number (quantized orbital angular momentum of electron) (l). (16) Total azimuthal or orbital quantum number (sum or resultant orbital angular momentum of two or more electrons) (L). (17) Kinetic potential (L). (18) In spectroscopy, shaded or displaced to longer waves (l).

L ANTENNA. A single-wire horizontal **antenna,** fed from one end, giving it an L-shaped appearance

L-CAPTURE. See **L-electron capture.**

L-ELECTRON. An electron having an orbit of such dimensions that the electron constitutes part of the second shell of electrons surrounding the atomic nucleus, counting out from the nucleus; orbitals in the L-shell are characterized by the **principal quantum number** value of 2 (i.e., the L-shell follows the K-, or innermost, shell).

L-ELECTRON CAPTURE. Electron capture from the L-shell by the atomic nucleus.

L-LINE. One of the lines in the L-series of **x-rays,** which are characteristic of the various elements, and are produced by **excitation** of the electrons of the L-shell.

L/M RATIO. The ratio of the number of internal conversion electrons from the L-shell to the number from the M-shell, emitted in the de-excitation of a nucleus. (See **K/L ratio.**)

L NETWORK. See **network, L.**

L-RADIATION. One of a series of **x-rays** characteristic of each element, that is emitted when that element, commonly as the metal, is used as an anti-cathode in an x-ray tube, and the electrons of its L-shell are excited.

"L-RING." See **magnetron, tuneable, methods of tuning.**

L SECTION. An elementary section of a network such as a **filter,** where the components are connected in the form of an L, i.e., one component in series with one side, and the other in shunt across the two sides of the circuit.

L-SHELL. The second layer of electrons about the **nucleus** of an atom, the first or innermost being the K-shell, which consists of two electrons in the case of all elements, except hydrogen. The L-shell contains eight electrons in the case of neon (atomic number 10) and of all elements of atomic number greater than ten. The L-shell is started with lithium (atomic number = 3), which has an L-shell containing one electron, and the L-shell of each atom of successively increasing atomic number has one more additional electron until neon, containing 8 electrons in its L-shell, is reached, at which point the L-shell is complete.

L-SYSTEM AND C-SYSTEM. In analyzing **collision** processes, it is convenient to use two frames of reference. In one, the L-system, the coordinate system is assumed to be fixed in the laboratory, or with respect to the observer. In the other, the C-system, the coordinate system is assumed to be fixed with respect to the center of mass of the colliding particles.

LABELED COMPOUND. A compound consisting, in part, of labeled molecules. By observations of radioactivity or isotopic composition this compound or its fragments may be followed through physical, chemical, or biological processes.

LABILE OSCILLATOR. A local oscillator whose frequency is controlled from a remote location.

LABORATORY SYSTEM. A frame of reference attached to the observer's laboratory and thus usually at rest relative to the surface of the earth. (See also **L-system and C-system.**)

LABY AND HERCUS METHOD FOR MECHANICAL EQUIVALENT OF HEAT. A continuous-flow method similar to that of **Reynolds and Moorby,** in which an electromagnetic brake instead of a hydraulic brake is used The method allows very high accuracy.

LABYRINTH BAFFLE. An acoustic device consisting of long air-chambers designed to absorb without reflection the energy radiated from the rear surface of the **loudspeaker** cone

LADD-FRANKLIN THEORY. This theory of vision assumes that in the rods and cones of the **retina** exist types of molecules which are affected and modified by the action of light.

LADDER NETWORK. See **network, ladder.**

LADENBURG, LAW OF. The speed of a **photoelectron** is proportional to the square root of the **excitation voltage.** Valid only when the speed is small compared with that of light.

LAG, ANGLE OF. When two related quantities, such as an alternating voltage and an alternating current, vary sinusoidally with time and have the same frequency, they may be expressed as

$$Q_1 = A \begin{Bmatrix} \sin \\ \cos \end{Bmatrix} (\omega t + \phi)$$

$$Q_2 = B \begin{Bmatrix} \sin \\ \cos \end{Bmatrix} \omega t$$

where A, B, and ω are constants. It is then said that Q_2 lags (behind) Q_1 and ϕ is known as the angle of lag if it is positive. If ϕ is negative its magnitude is the angle of lead and Q_2 is said to lead Q_1.

LAGRANGE BRACKET. Lagrange bracket, of two dynamical variables x,y of a classical dynamical system with generalized coordinates q_k, generalized momenta p_k, is given

$$[x,y] = \sum_k \left(\frac{\partial q_k}{\partial x}\frac{\partial p_k}{\partial y} - \frac{\partial q_k}{\partial y}\frac{\partial p_k}{\partial x} \right).$$

(See **coordinates and momenta, generalized.**)

LAGRANGE DENSITY. Integrand L of an integral which is such that the conditions that it should be an extreme are the equations of motion of a dynamical system of fields. L is a function of the fields, their time and space derivatives, and the coordinates and time

LAGRANGE EQUATIONS (SOMETIMES CALLED EULER-LAGRANGE EQUATIONS). A set of equations of motion for a dynamical system. In the case where the system is conservative the equation of motion for the ith particle is written:

$$\frac{d}{dt}\frac{\partial L}{\partial \dot{q}_i} - \frac{\partial L}{\partial q_i} = 0$$

where L is the Lagrangian function or kinetic potential; q_i is the generalized coordinate of ith particle ($i = 1, 2, 3, \cdots n$, where n is the number of **degrees of freedom** of the system); $\dot{q}_i$ is the generalized velocity of ith particle

These equations have the advantage over Newton's equations that any kind of coordinates may be used. (See **coordinates and momenta, generalized.**)

For non-conservative systems a set of equations can be written:

$$\frac{d}{dt}\frac{\partial K}{\partial \dot{q}_i} - \frac{\partial K}{\partial q_i} = Q_i$$

where Q_i is the generalized force such that $Q_i\delta q_i$ represents work done by Q_i when the coordinate q_i changes by δq_i; K is the kinetic energy of the system.

LAGRANGE FIELD EQUATIONS. The equations, for any field $\psi(x_\mu)$ ($\mu = 1 \cdots 4$, x_4 = constant times the time)

$$\frac{\partial L}{\partial \psi} = \sum_{\mu=1}^{4} \frac{\partial}{\partial x_\mu}\left(\frac{\partial L}{\partial\left(\dfrac{\partial \psi}{\partial x_\mu}\right)}\right)$$

where L is the **Lagrange density,** assumed here not to involve derivatives higher than the first of the fields with respect to the coordinates and time.

LAGRANGE FORMULA FOR INTERPOLATION. Used when $(n + 1)$ pairs of values are given for $y = f(x)$, but not necessarily at equally-spaced increments of x or y. Let the given number pairs be (x_0,y_0), (x_1,y_1), $\cdots$, (x_n,y_n). Then for any desired value of x within this interval

$$y = \frac{(x - x_1)(x - x_2) \cdots (x - x_n)}{(x_0 - x_1)(x_0 - x_2) \cdots (x_0 - x_n)} y_0 + \frac{(x - x_0)(x - x_2) \cdots (x - x_n)}{(x_1 - x_0)(x_1 - x_2) \cdots (x_1 - x_n)} y_1 + \cdots \frac{(x - x_0)(x - x_1) \cdots (x - x_{n-1})}{(x_n - x_0)(x_n - x_1) \cdots (x_n - x_{n-1})} y_n.$$

Because of the symmetry in the result, x and y may be interchanged so that **inverse interpolation** may be effected.

LAGRANGIAN FUNCTION OR KINETIC POTENTIAL. The difference between the kinetic energy and potential energy of a dynamic system. It is generally symbolized by L.

LAGRANGE-HELMHOLTZ EQUATION. See **Helmholtz equation.**

LAGRANGE IDENTITY. See **adjoint equation.**

LAGRANGE MULTIPLIER. A method of solving **isoperimetric problems** in the **calculus of variations.** Suppose $u = f(x_1, x_2, \cdots, x_n)$ and that $m < n$ accessory conditions $\phi_1(x_1, x_2, \cdots, x_n) = 0$; $\phi_2 = 0$; $\cdots$; $\phi_m = 0$ are also given. Use m constants, L_i, called the **Lagrange multipliers,** and form the equation

$$F = f + L_1\phi_1 + L_2\phi_2 + \cdots + L_m\phi_m.$$

If the n derivatives are required to vanish

$$\partial F/\partial x_1 = 0; \quad \partial F/\partial x_2 = 0; \quad \cdots \quad \partial F/\partial x_n = 0$$

these relations, together with the m conditions $\phi_i = 0$, make it possible to determine the $(m + n)$ variables so that an **extremal** or stationary value of u results.

LAGRANGE THEOREM. For a single refracting surface of sufficiently small **aperture,** the **Abbe sine condition** reduces to

$$ny\theta = n'y'\theta'$$

which is known as the **Lagrange theorem;** sometimes called the Smith-Helmholtz law.

LAGUERRE DIFFERENTIAL EQUATION. The linear equation

$$xy'' + (1 - x)y' + ny = 0$$

having a simple **pole** at the origin. Its solutions are the **Laguerre polynomials.** Differentiation of the equation k times and replacement of the kth derivative by y gives

$$xy'' + (k + 1 - x)y' + (n - k)y = 0$$

which is the **associated Laguerre equation** with solutions as **associated Laguerre polynomials.** These functions occur in the quantum mechanical problem of the hydrogen atom

LAGUERRE POLYNOMIAL. A solution of the **Laguerre differential equation.** The **associated polynomials** may be defined by the equivalent expressions

$$L_n^{(k)}(x) = \frac{e^x x^{-k}}{n!} \frac{d^n}{dx^n} (e^{-x}x^{n+k})$$

$$= \sum_{i=0}^{n} \binom{n + k}{n - i} \frac{(-x)^i}{i!}.$$

The special case of $k = 0$ gives the **Laguerre polynomials**

$$L_n(x) = 1 - \binom{n}{1} x + \binom{n}{2} \frac{x^2}{2!} - \binom{n}{3} \frac{x^3}{3!} + \cdots.$$

Both kinds may also be expressed in terms of the **Gauss hypergeometric series** and by **generating functions.** They are also related to the **Hermite polynomials** and the **Bessel functions.**

LAMB-RETHERFORD SHIFT. See **Lamb shift.**

LAMB SHIFT. The displacement between the $2S_{1/2}$ and $2P_{1/2}$ levels of hydrogen, which in the absence of **radiative corrections** would be zero due to the **Coulomb degeneracy.** Experimental value obtained by Lamb and Retherford

$$E_{2S_{1/2}} - E_{2P_{1/2}} = 1057.8 \pm 0.1 \text{ megacycles}$$

in agreement with theoretical value. Of this, -27 mc arises from **vacuum polarization,** the rest from **self-energy** corrections. The term is now used to indicate the displacement of any bound state level due to radiative corrections.

LAMBDA. (1) Free path or mean free path (λ or l). (2) Tait free path (λ_T or l_T). (3) Latent heat of evaporation (λ or L). (4) Equivalent conductivity (Λ). (5) Microliter (λ). (6) Wavelength (λ). (7) Linear charge density (λ). (8) Nuclear dissociation energy

(Λ). (9) Mass per unit length (λ). (10) Disintegration or decay constant (λ). (11) Level width (Λ). (12) Absolute value of the projection of the resultant orbital angular momentum on the molecular axis (Hund's cases *a* and *b*) (Λ). (13) Absolute value of the component of the orbital angular momentum of a single electron parallel to the molecular axis (λ).

LAMBDA LIMITING PROCESS. Method of defining a point electron as the limiting case in which a time-like vector λ_μ tends to zero. Thus the field at the **space-time coordinate** x_μ of the electron is

$$\underset{\lambda_\mu \to 0}{\text{Lt}} \; E(x_\mu + \lambda_\mu) \quad \text{with} \quad \lambda_\mu\lambda_\mu < 0.$$

LAMBDA POINT (λ-POINT). (1) The temperature at which the transition of helium I to helium II takes place Under **orthobaric** conditions, liquid helium undergoes this change at 2.19°K; but the temperature at which this change occurs decreases with increasing external pressure. (See also **helium, liquid.**) (2) The temperature at which the **specific heat** of a substance reaches a sharp maximum and then drops suddenly with increasing temperature. Such λ-points are characteristic of many second-order phase changes, such as those which take place in **order-disorder transitions** and at the **Curie point** of ferromagnetic or ferroelectric materials.

LAMBERT. A unit of **luminance** equal to $1/\pi$ **candle** per square centimeter, and, therefore, equal to the uniform luminance of a perfectly diffusing surface emitting or reflecting light at the rate of one **lumen** per square centimeter.

LAMBERT COSINE LAW. The **intensity** from a surface element of a perfectly diffuse radiator is proportional to the cosine of the angle between the direction of emission and the normal to the surface. An element of a surface which obeys this law will appear equally bright when observed from any direction.

LAMBERT LAW. See **Bouguer law** and **Beer law.**

LAMP. In its derivation, this term denoted a device for producing light by combustion; its application has been extended to cover a wide range of devices for giving light and/or other radiant energy.

LAMP, ARC. A source of light consisting essentially of **electrodes** between which an electric **arc** is maintained.

LAMP, ELECTRIC. The principal electric lamps are the **arc lamp,** vapor lamp, the incandescent resistance lamp and the fluorescent lamp. The common vapor lamps in use now are the mercury-vapor, giving a bluish-green light, and the sodium lamp, giving a yellow or orange light. Other gases are used for special purpose lamps such as advertising displays where a wider range of colors is desirable.

In the ordinary incandescent lamp, light is emitted from a highly heated resistance wire having a high melting point so that it may remain in a state of incandescence many hours without fusing or breaking The resistor, or filament, is hermetically sealed in a glass bulb, which is evacuated, or which is filled with inert gas, such as nitrogen. Most modern incandescent lamps have filaments of drawn tungsten wire

The most recent development in the lamp field is the fluorescent lamp which is a type of vapor lamp, but converts the radiation from the ionized vapor into a more usable type by means of a fluorescent coating on the inside of the lamp. These lamps are tubular in form, contain a filament-type electrode at each end, have the inner wall of the tube coated with some phosphor (a material which will fluoresce under ultra-violet excitation) and are filled with mercury vapor at low pressure. The discharge is rich in ultra-violet radiation which excites a visible radiation in the fluorescent coating of the tube. The ballast limits the current to a safe value since the discharge is not inherently self-limiting. The color of the light may be controlled by the type phosphor used for coating the lamp. The efficiency is much higher than incandescent lamps, for example, a 40-watt fluorescent lamp will produce about the same number of lumens as a 150-watt incandescent lamp. The better control of color of light and the better efficiency are causing a widespread change-over to this type lighting in many applications.

LAMP, FILAMENT. A device for producing light by an electrically-heated wire in a glass

bulb that has been evacuated, or partially filled with an inert gas.

LAMP, GLOBAR. See **globar.**

LAMP, HARCOURT. A standard of **intensity of illumination,** which produces light by the combustion of pentane.

LAMP, KROMAYER. A mercury vapor lamp, used as a source of **ultraviolet radiation.**

LAMP, MERCURY VAPOR. A lamp containing mercury in a previously-evacuated bulb or tube. The mercury-vapor conducts electricity between the electrodes, and yields a blue-green light, rich in ultraviolet and near infrared, as well as visible radiation.

The mercury vapor may also be excited to radiation in an electrodeless tube by a high frequency current in a coil surrounding the tube. By using mercury 198 (Hg^{198}) obtained from atomic piles, in the tube, spectral lines are obtained which are superior to those of cadmium as wavelength standards.

LAMP, NERNST (NERNST GLOWER). An electric lamp whose **luminosity** proceeds from a short slender rod of ceramic material, largely zirconium oxide, heated by an electric current. The lamp must be separately heated to start, since at room temperature the material is essentially an insulator The lamp has a negative temperature coefficient of resistance and hence the current should be controlled by a ballast resistance. The lamp does not need to be enclosed, hence is frequently used as a light source for infrared **spectrometers,** thereby avoiding the absorption losses of any enclosing glass bulb. (See also **globar.**)

LAMP, QUARTZ. A lamp having quartz bulb to transmit ultraviolet radiation; such lamps are commonly of the mercury-vapor type, or of other light-source rich in ultraviolet radiation.

LAMP, SPECTRUM. A lamp giving a nonluminous flame, used in the **spectroscopic** examination of radiation from solids, liquids, or solutions introduced into the flame.

LAND. The surface between adjacent grooves of a phonograph record or of a **diffraction grating.** The term also applies to the high spots in an incompletely ground or polished optical surface.

LAND BREEZE. At night air in contact with land cools faster than that in contact with water. When sufficient difference in temperature arises between the land and the sea air, there springs up a breeze flowing offshore from cold land onto warm water. This wind is known as the land breeze. Its basic cause lies in the fact that constant pressure and density surfaces intersect and form a solenoidal field; the resulting circulation tends to bring the density surfaces parallel with the pressure surfaces.

LANDAU DIAMAGNETISM. See **diamagnetic susceptibility of conduction elections.**

LANDÉ Γ-PERMANENCE RULE (SPECTROSCOPY). For a given multiplet spectral term, i.e., given S and L, or given j_1 and j_2, the sum of all the Γ factors for terms with the same magnetic quantum number M is a constant independent of the field strength. The Γ factor is defined for an electron by the expression:

$$\Gamma = a\sqrt{l(l+1)}\sqrt{s(s+1)}\cos(ls)$$

$$= \frac{a}{2}(j(j+1) - l(l+1) - s(s+1))$$

where l, s and j are vectors and a is a constant for the given multiplet.

For any doublet level, the wave number is given by the expression:

$$\bar{\nu} = \bar{\nu}_0 - \Gamma.$$

where $\bar{\nu}_0$ is the value for the center of gravity of the doublet.

LANDÉ SPLITTING FACTOR (SPECTROSCOPY). A quantity (g) which appears in the formula for the change in energy in a magnetic field for a level of quantum number J, which takes the form:

$$\Delta E = Mhg\sigma$$

where ΔE is the change in energy $M = J$, $J - 1, \cdots -J$, h is the Planck constant and $\sigma = eH/4\pi mc$, where e is the electronic charge in esu, H is the field intensity, m is the magnetic quantum number, and c is the speed of light.

Landé deduced for g in a "weak" field, and with LS-coupling the empirical relation,

$$g = 1 + \frac{J(J+1) + S(S+1) - L(L+1)}{2J(J+1)}.$$

LANDING BEACON. A radio transmitter used to generate a **landing beam.**

LANDING BEAM. A radio beam, highly directional in both elevation and azimuth, used to guide aircraft to safe landings during poor visibility conditions.

LANDOLT BAND. A dark band sometimes appearing in the field of crossed **nicols** with an intense source such as the sun; due to the light being not strictly parallel.

LANDSBERGER METHOD. See **boiling point, methods of determining elevation of.**

LANGEVIN FORMULA. The **Weiss theory of ferromagnetism** yields an expression, for the quotient of the average component of atomic magnetic moment, parallel to the field, by the atomic moment,

$$\frac{\bar{\mu}_A}{\mu_A} = \operatorname{ctnh}\frac{\mu_A H}{kT} - \frac{kT}{\mu_A H}.$$

For $\mu_A H \ll kT$, as it is in paramagnetic materials, the atomic susceptibility is

$$\chi_A = \frac{N_0\bar{\mu}_A}{H} = \frac{N_0\mu_A{}^2}{3kT}$$

where N_0 is the number of atoms per gram-atom. (See also **Langevin theory of diamagnetism.**)

LANGEVIN THEORY OF DIAMAGNETISM. Langevin considered the orbital motion of an electron in a atom to be an equivalent **current loop.** Application of a **magnetic field** induces an emf in the orbit, speeding up the electron and increasing the magnetic moment of the current loop by the amount

$$\Delta m = \frac{e^2Hr^2}{4mc^2}$$

which implies a **susceptibility** per atom of $-e^2r^2/4mc^2$ or N_0 times as much per gram-atomic weight. Averaging over all orbital radii and orientations, the atomic susceptibility becomes

$$\chi_A = -\frac{N_0e^2\Sigma\bar{r}^2}{6mc^2}.$$

(See also **Langevin formula.**)

LANGMUIR ADSORPTION ISOTHERM. The relation between the amount of gas adsorbed in a unimolecular layer by a definite mass of adsorbent, and the pressure. One form of this relationship is the following:

$$\theta = \frac{bp}{1 + bp}$$

where θ is the fraction of the surface covered by adsorbed gas, b is a constant, p the gas pressure. This equation is commonly known as the Langmuir isotherm. It can be obtained in the form:

$$\frac{p}{X/m} = \frac{1}{K_1K_2} + \frac{p}{K_2}$$

in which X is the amount of gas absorbed, m is the mass of adsorbent, p is the gas pressure, and K_1 and K_2 are constants. As is evident from the relationship, by the plotting of $\frac{p}{X/m}$ against p, a straight line should be obtained

LANGMUIR DARK SPACE. The dark space surrounding a negative electrode, positioned in the **positive column** of a **glow discharge.**

LANGMUIR METHOD FOR THE RATE OF VAPORIZATION OF METALS. Langmuir used a dynamical method based on the measurement of the rate of loss of weight of a metal wire heated in a vacuum The wire was contained in a bulb, and was heated by an electric current, the temperature being measured optically. At the low pressures used in the experiments, the **mean free path** of the molecules was long compared with the size of the bulb, and consequently all the molecules leaving the wire struck the walls, to which they adhered, since the temperature of the walls was comparatively low. In these conditions it can be shown from kinetic theory that the maximum rate of evaporation μ in grams per unit area per second is given by

$$\mu = p\sqrt{M/2\pi RT},$$

where M is the molecular weight of the vapor, R the gas constant, T the absolute temperature, and p is the vapor pressure when the metal is in equilibrium with its vapor.

Langmuir assumed that the actual rate of evaporation was given by this expression, i.e., that the coefficient of condensation was unity.

Later work appears to show that this view was not justified.

LANIER EFFECT. A photographic effect observed by A. Lanier (1896) involving acceleration of development by the addition of potassium iodide to the developer, or by bathing the plate or film in a solution of potassium iodide before development. The effect is more marked with developers of low reduction potential, particularly hydroquinone, and is hardly apparent with developers of high reduction potential.

LANGUAGE. A set of symbols, with rules for the combination of these symbols, which may be used to express information, such that the sum of the number of symbols and the number of rules is much smaller than the number of distinct expressible meanings.

LANTHANIDE CONTRACTION. The decreasing sequence of crystal radii of the tripositive rare-earth ions with increasing atomic number in the group **lanthanum** through **lutecium** (i.e., in elements of atomic numbers from 57 through 71, the so-called **lanthanide series**).

LANTHANIDE SERIES. The rare earth elements of atomic number 57 through 71, which have chemical properties similar to **lanthanum** (number 57)

LANTHANUM. Rare earth metallic element. Symbol La. Atomic number 57.

LAP (OPTICAL). (1) A disk, commonly of cast iron, mounted to rotate on an axis normal to the face of the disk. The face may be either flat or curved. Used to grind optics prior to polishing. (2) The process of grinding **optics** prior to polishing. Commonly optics are ground to approximate shape by use of a loose abrasive and water. Carborundum (silicon carbide) and corundum or emery (aluminum oxide) of different particle size are the conventional lapping-compounds. Lapping is now being replaced by cutting or milling with diamond tools.

LAPEL MICROPHONE. See **microphone, lapel.**

LAPLACE DEVELOPMENT OF A DETERMINANT. A method of finding the numerical value of a **determinant.** Let its order be n and A^{ik} be the **cofactor** to the element A_{ik}. Then

$$|A| = \det A = \sum_{i=1}^{n} A_{ik}A^{ik}$$

$$= \sum_{i=1}^{n} A_{ki}A^{ki}; \quad k = 1, 2, \cdots, n.$$

LAPLACE EQUATION. A second-order **partial differential equation** which, in **vector** form, is $\nabla^2\phi = 0$. It is the **homogeneous** case of **Poisson's equation.** Its solutions, the scalar quantity ϕ, occur in problems involving steady-state temperatures, gravitational and electric potentials, hydrodynamics of ideal fluids, and many other physical phenomena. The equation is usually solved by the method of **separation of variables** in a suitable **curvilinear coordinate system** and with **boundary conditions** imposed by physical requirements. Such solutions are called **harmonic functions.** In two dimensions, an **analytic** function of the complex variable must satisfy Laplace's equation.

LAPLACE EQUATION, SOLUTIONS OF. In three dimensions, the **Laplace equation** is satisfied by any linear combination of terms of the type

$$r^n P_n{}^m(\cos\theta)e^{jm\phi}$$

$$r^{-(n+1)} P_n{}^m(\cos\theta)e^{jm\phi}$$

where r, θ, ϕ comprise a spherical coordinate system. The solutions on the surface of a unit sphere are $P_n{}^m(\cos\theta)e^{jm\phi}$ and are called "tesseral harmonics" (of nth degree and mth order). Those of zero$^{\text{th}}$ order, $P_n(\cos\theta)$, are called "zonal harmonics." In general, any solution of the Laplace equation is called a harmonic function. The zonal harmonics are also known as **Legendre polynomials,** and the tesseral harmonics as associated Legendre polynomials.

In two dimensions, rectangular coordinates, any analytic function of the complex variable $z = x + jy$ satisfies the Laplace equation by virtue of the **Cauchy conditions** for analyticity. In fact, the real and imaginary parts of $f(z)$ satisfy Laplace's equation separately, and the curves $\operatorname{Re} f(z) = C_1$, $\operatorname{Im} f(z) = C_2$ intersect at right angles. These relations are important in the theory of **conformal** mapping and its application to electrostatic problems.

LAPLACE EQUATION, USE IN FLUID DYNAMICS. An irrotational incompressible flow can be specified by a velocity potential which satisfies the **Laplace equation at all**

points in the flow. The problem of determining the velocity potential function from the boundary conditions of the flow system may be solved by methods that usually involve expansion in suitable orthogonal functions, the choice of the functions depending on the particular type of symmetry. Many problems lend themselves to representation in spherical polar coordinates and then the general solution is

$$\Phi(r,\theta,\phi) = \sum_n \sum_m (a_1 r^n + a_2 r^{-n-1}) P_n{}^m(\cos\theta) e^{\pm im\phi}$$

where r,θ,ϕ are the coordinates, $P_n{}^m(\cos\theta)$ is a Legendre polynomial, n,m are integers.

LAPLACE LAW. See **Ampere law.**

LAPLACE TRANSFORM. The function $f(p)$ is the **Laplace transform** of $F(x)$, where

$$f(p) = \int_0^\infty e^{-px}F(x)dx;$$

$$F(x) = \frac{1}{2\pi i}\int_{c-i\infty}^{c+i\infty} e^{px}f(p)dp.$$

In the latter form, the constant c is any real number such that

$$\int_0^\infty e^{-cx}|f(x)|dx$$

is **bounded.** (Refer also to the entry for the **Fourier transform.**)

LAPLACIAN. (1) The **vector operator**

$$\text{div } \mathbf{grad} = \nabla\cdot\nabla = \nabla^2.$$

In rectangular coordinates its components are $\partial^2/\partial x^2$, $\partial^2/\partial y^2$, $\partial^2/\partial z^2$.

(2) This term has been used, in nuclear technology, in place of the negative of **buckling.**

LAPSE RATE. The rate at which temperature decreases or lapses with altitude. It is the vertical temperature gradient Since temperature normally decreases with altitude in the **troposphere,** it is convenient to assign positive values to the rate of temperature change with altitude Lapse rate, therefore, is defined as the rate of change of temperature with altitude and is positive when the temperature decreases.

LAPSE RATE, AUTOCONVECTION. See **autoconvection, lapse rate.**

LARMOR PRECESSION. The motion which a charged particle or system of charged particles subject to a central force directed towards a common point experiences when under the influence of a small uniform magnetic field If a coordinate system is chosen which rotates about the direction of the magnetic field with an angular velocity

$$\omega = -\frac{q}{2mc}H,$$

where ω is the angular velocity, q is electric charge in esu, m is mass, c is the velocity of light, H is magnetic field strength in emu, then the motion in this system of coordinates is the same as the motion referred to a coordinate system fixed in space without a magnetic field This is called the Larmor theorem

The application of this principle arises almost exclusively in the description of the motion of atoms and electrons in magnetic fields. (See **precession.**)

LARMOR THEOREM. See **Larmor precession.**

LARSEN POTENTIOMETER. See **potentiometer, Larsen.**

LATENT PHOTOGRAPHIC IMAGE. The invisible, but developable, image formed on exposure of a light-sensitive emulsion to light A complete theory of the latent image has not yet been developed but it seems certain that minute sensitivity-centers of silver sulphide or colloidal silver attached to the silver halide crystals are involved.

LATERAL MAGNIFICATION. **Linear magnification** measured normal to the optical axis. If dy is an element of distance in object space normal to the optical axis of a system and dy' is the conjugate element in image space, then dy'/dy is the lateral magnification.

LATERAL RECORDING. A disk **recording** in which an essentially constant-depth groove is cut in the plane of the disk.

LATERAL SPHERICAL ABERRATION. The difference between the reciprocals of the image distances for paraxial and rim rays. (See also **longitudinal spherical aberration.**)

If S' and S'_h are the image distances for paraxial rays and rays which strike a lens a distance h from its center, respectively, then $S' - S'_h$ is the longitudinal spherical aberration, and $(1/S'_h) - (1/S')$ is the lateral spherical aberration.

LATTICE. (1) A regular array of points in space, as for example, the sites of atoms in a crystal. (See **space lattice.**) (2) In a nuclear **reactor,** structure of discrete bodies of fissionable material and non-fissionable material (especially **moderator**) arranged in a regular geometrical pattern. Most heterogeneous reactors have a lattice structure. (3) In mathematics, a partially-ordered set in which any two elements have a greatest lower bound and a least upper bound, the greatest lower bound of a and b being an element c such that $c \leqq a$, $c \leqq b$, and if $d \leqq a$, $d \leqq b$, then $c \geqq d$, and the least upper bound being defined analogously.

LATTICE COMPOUNDS. Compounds formed between definite **stoichiometric** amounts of two molecular species which owe their stability to packing in the crystal lattice, and not to ordinary **valence** forces.

LATTICE CONSTANT. A length representing the size of the **unit cell** in a **crystal lattice.** In a **cubic** crystal, this is just the length of the side of the unit cell, but such a simple definition is not in general possible, and the lattice constant must be chosen according to the geometry of the structure in each case.

LATTICE DEFECT. See **defect.**

LATTICE DIMENSIONS. According to the **Bragg formula** the spacing of the **atomic planes** can be deduced from the **X-ray diffraction** pattern and a knowledge of the X-ray wavelength, which can itself be measured by diffraction from a ruled **grating.**

LATTICE DYNAMICS. A branch of the theory of the solid state, dealing with the properties of the **thermal vibrations** of **crystal lattices.**

LATTICE ENERGY OF CRYSTAL. The decrease in energy accompanying the process of bringing the ions, when separated from each other by an infinite distance, to the positions they occupy in the stable lattice. It is made up of contributions from the electrostatic forces between the ions, from the repulsive forces associated with the overlap of **electron shells,** from the **van der Waals** forces, and from the **zero-point energy.** (See **Born-Mayer equation.**)

LATTICE NETWORK. See **network, lattice.**

LATTICE PLANE. See **atomic plane.**

LATTICE SUM. In general, any sum whose terms are functions of the positions of points in a space **lattice.** The term is applied particularly to those sums involved in evaluating the **Coulomb energy** of an **ionic crystal,** where the magnitude of each term depends on the inverse distance of the lattice point from the origin, with a sign depending on the charge of the ion at that point. Such sums are difficult to evaluate directly, as they converge only very slowly, but special methods have been devised to calculate them. (See **Evjen method, Ewald method.**)

LATTICE VIBRATION. A **thermal vibration** of a **crystal lattice.**

LATTICE WAVE. See **phonon.**

LATUS RECTUM. A chord perpendicular to an axis of a **conic section** and passing through a focus. If the section is an **ellipse,** the axis is the major axis; if a **hyperbola,** the transverse axis. (See also **parabola.**)

LAUE PHOTOGRAPH METHOD. A method of **X-ray analysis** of **crystal structure** in which a beam of X-rays of all wavelengths is passed through a thin slice of the crystal and the diffracted beams received as a series of spots on a photographic plate. It can easily be seen, from the **Bragg equation,** that each **atomic plane** will give rise to a spot, which fixes its orientation, and hence the symmetry of the crystal structure. It is difficult, however, to determine the **structure factors** directly by this method, because of uncertainty in the spectrum of the incident X-rays.

LAUNCHING. The name sometimes applied to the process of transferring energy from a **coaxial cable** or transmission line to a **waveguide.**

LAURENT HALF-SHADE PLATE. The Laurent **half-shade plate** consists of a semicircular **half-wave plate** of quartz or other

crystal set between the **polarizer** and **analyzer** and close to the former, with its optic axis at a small angle with the **principal section** of the polarizer.

LAURENT POLARIMETER. A **polarimeter** consisting of a monochromatic filter, a polarizing nicol, a **half-shade plate,** a tube for unknowns to be studied, an analyzing **nicol** and an **eye lens** focused on the half-shade plate Used to measure the rotatory power of liquids and crystals.

LAURENT SERIES. A generalization of the **Taylor series,** making it possible to develop a function of the **complex variable** about a **singular point** $z = z_0$. The result is a two-way power series (positive and negative powers)

$$f(z) = \sum_{n=-\infty}^{\infty} a_n(z - z_0)^n$$

with coefficients given by

$$a_n = \frac{1}{2\pi i}\int_C \frac{f(t)dt}{(t - z_0)^{n+1}}.$$

The **contour** consists of a circle about $z = z_0$ The size of the circle is limited only by the condition that $f(x)$ shall be analytic everywhere within the circle, except at the singularity. If there are an infinite number of negative powers in the series, $f(z)$ has an **essential singularity** at z_0; if a_{-k} is not zero and all other coefficients $a_n = 0$ for $n < -k$, the singular point is a **pole** of order k

LAURITSEN ELECTROSCOPE. See **electroscope, Lauritsen.**

LAW. A statement describing a general truth or general relationship, which formulates the conditions applying to various phenomena or their relationships.

LAW OF APPEARANCE OF UNSTABLE FORMS. The **unstable** forms of **monotropic** substances are obtained from a liquid or vapor state before the **stable** form appears.

LAW OF AREAS. A particle in motion under the influence of any central force moves in such a way that the radius vector sweeps out equal areas in equal intervals of time. The law is a direct consequence of the conservation of angular momentum. Kepler's second law (see **laws of Kepler**) is a special case.

LAW OF COMPOSITION OF FORCES. See **equilibrium; forces, parallelogram of; polygon of.**

LAW OF CONSERVATION OF ANGULAR MOMENTUM. If the total external **torque** on a rigid body or a system of particles about a point vanishes, the total **angular momentum** of the system about this point is a constant (See also **moment of momentum.**)

LAW OF CONSERVATION OF MECHANICAL ENERGY. For a **conservative system** the mechanical energy, which is equal to the sum of the kinetic energy (see **energy, kinetic**) and potential energy (see **energy, potential**) is always equal to a constant determined by the initial conditions of the motion.

LAW OF RADIOACTIVE DECAY. See **radioactive decay, law of.**

LAW OF RADIOACTIVE DISPLACEMENT. See **radioactive displacement, law of.**

LAW OF RATIONAL INTERCEPTS. See **Haüy law.**

LAW OF SINES (THREE FORCES ACTING AT A POINT). If a particle is in equilibrium under the influence of three forces acting at a point, the ratios of each force to the sine of the angle between the other two forces are equal (See **equilibrium.**)

LAWS OF KEPLER. Three laws of planetary motion first enunciated by Kepler at the beginning of the seventeenth century (1) The planets describe, relatively to the sun, ellipses of which the sun occupies a focus. (2) The radius vector of each planet traces out equal areas in equal times (3) The squares of the periods of revolution of any two planets vary as the cubes of the major axes of their orbits.

LAWRENCE TUBE. See **chromatron.**

LAYER(S), E, F, (F_1 AND F_2) AND D. See **E layer, F layer,** and **D layer.**

LAYER LATTICE. A solid structure consisting of sheets of atoms, not necessarily in one plane, extending throughout the whole crystal and separated from one another by a distance which is too large for chemical bond-

ing. Graphite is the familiar example, and shows the characteristic cleavage into thin flakes.

LAYER LINES. In the **rotating crystal** type of apparatus for the **X-ray analysis** of **crystal structure,** all lattice planes having the same spacing in the direction parallel to the axis of rotation will produce diffraction spots lying on more or less horizontal lines.

LAYER OF CHARGE. A "simple" layer is a sheet of charge of one sign, such as the surface charge on a charged conductor. (See also **double layer.**)

LAYER OF CHARGE, STRENGTH OF. The strength of a **double layer** is the **dipole moment** per unit area.

LEAD. Metallic element. Symbol Pb. Atomic number 82

LEAD, ANGLE OF. See **lag, angle of.**

LEAD-IN SPIRAL. The blank groove of high pitch used to guide the stylus into the modulated grooves of a **disk recording.**

LEAD NETWORK. A **transducer** whose output voltage leads the input voltage over a certain range of frequencies. Sometimes it may be referred to as a differentiating network.

LEAD SCREW. (1) The screw which drives the **cutting head** across a **recording disk** in the initial recording process. The groove pitch produced may be constant, or in later high-fidelity systems, may be adjusted according to the signal strength being recorded. (2) The screw which controls the longitudinal motion of a tool on a lathe, grating engine, or similar device.

LEADING-EDGE PULSE TIME. See **pulse time, leading-edge.**

LEAKAGE CURRENT The current which results from charge flowing or "leaking" along the surface or through the body of an insulator. Except under abnormal conditions such as dirty or moist surfaces or in electronic circuits having very minute currents the leakage is usually negligible.

LEAKAGE, NEUTRON. The loss of neutrons of a specified energy range from a given region of a nuclear **reactor** due to their motion. The leakage spectrum is the energy distribution of neutrons leaving the reactor.

LEAKAGE RADIATION. See **radiation, leakage.**

LEAKAGE REACTANCE. The inductive reactance caused by the flux which links only one coil of a **transformer.** The useful flux, of course, link both windings and is the medium of transfer of energy between them. Leakage reactance is one of the major internal impedance components of the transformer.

LEAD CONTROL. The control of the stability of **feedback systems** by the use of **lead networks.**

LEAST ACTION, PRINCIPLE OF. This principle, first enunciated rather loosely by Maupertuis in the 18th century, states that the actual motion of a conservative dynamical system from P_1 to P_2 takes place in such a way that the **action** has a stationary value with respect to all other possible paths between P_1 and P_2 corresponding to the *same energy.* (Cf. **Hamilton principle.**)

LEAST-ENERGY PRINCIPLE. A principle relating to stable equilibrium, and having very wide application. If a system is in stable equilibrium, any slight change in its condition or configuration requiring the performance of work will put it out of equilibrium, so that, if the system is now left to itself, it will return to its former state and in so doing will give up the energy imparted when it was disturbed. Consider, for example, a block of wood floating in a pail of water. If the block is lifted slightly, work is done and the center of mass of the wood-water system as a whole is raised, so that it now has more potential energy. The same would be true if the block were pushed a little farther into the water. In either case, when the block is released, it resumes its former level and the potential energy of the system diminishes to its former minimum value. This illustrates the general principle, which is that a system is in stable equilibrium only under those conditions for which its potential energy is at a minimum.

The principle of least energy is one aspect of the principle of virtual work. (Cf. **potential energy.**)

LEAST SQUARES FITTING. A method of combining experimental date which show the value of a dependent variable y for various values of the independent variable x in such a way as to establish the best relation between y and x. In the simplest and most common application, it is known that $y = a + bx$, where a and b are constants whose values are to be determined. The method leads to values of a and b such that the sum of the squares of the deviations of the observed values of y from the values predicted by the equation is minimized. For a detailed discussion see Worthing and Geffner, *Treatment of Experimental Data*, Wiley (1943).

LEAST TIME, PRINCIPLE OF. See **Fermat principle.**

LEAST WORK. The three equations of static **equilibrium** are insufficient to determine the analysis of certain types of structures which, in consequence, are called statically indeterminate structures. The analysis of such structures belongs to the general subject of mathematical theory of elasticity. Several methods of attack have been devised, but none has had so wide an application as the principle of least work. When a structure, either simple or complex, is loaded, there is a certain amount of energy stored in it by virtue of the deformation of its several elastic components. The theory of least work is based on the fact that the natural phenomena attending the deflection of a stressed structure is that the individual parts will be so deflected that the load will be carried with a minimum storage of energy in the elastic members. In the least-work theory, there are two basic propositions. The first is that the linear displacement of the point of application of a load of an **indeterminate structure**, in the direction of the load, equals the first **derivative** of the energy stored in the elastic structure, taken with respect to the load. The second theorem is that the magnitudes of statically indeterminate reaction forces are such as to make the elastic energy of the system the least possible. (Cf. **equilibrium.**)

LE CHATELIER PRINCIPLE. A general law for physical systems which states that: If a system is subjected to a constraint whereby the equilibrium is modified, a change takes place, if possible, which partially annuls the constraint.

LECHER OSCILLATOR. See **electric oscillations; electric waves.**

LECHER WIRES. A special type of transmission **line** used primarily for the measurement of frequencies in the high radio-frequency range (see **frequency meter**). Basically they consist of two parallel wires a few wavelengths (in terms of the frequency to be measured) long which are adjustable in length. While usually adjusted by sliding a shorting bar along the wires they are sometimes fixed in physical length, either open or short-circuited at the remote end, and varied electrically by tuning a series condenser. In any event, if the system is coupled to a source of high frequency the induced waves will be reflected from the end and if the line is electrically an integral number of half-wavelengths long standing waves will result. The nodes or anti-nodes of these may be detected with a suitable detector and the spacing of corresponding points will be a half-wavelength apart, thus allowing the frequency to be calculated.

LEFT-HAND RULE (FOR MOTOR ACTION). See **right-hand rule.**

LEFT-HANDED (COUNTER-CLOCKWISE) POLARIZED WAVE. See **wave, left-handed (counter-clockwise) polarized.**

LEGENDRE EQUATION. A second-order **differential equation**

$$(1 - x^2)y'' - 2xy' + n(n + 1)y = 0.$$

It is a special case of the **associated Legendre equation**

$$(1 - x^2)y'' - 2xy' + \left[n(n + 1) - \frac{m^2}{1 - x^2}\right] y = 0$$

which in turn is a special case of the **Gauss hypergeometric equation.** Both Legendre equations have **singular points** at $x = \pm 1, \infty$ and if m,n are integers the solutions are **Legendre polynomials.** For non-integral values of these parameters, the solutions are Legendre functions. (See also **harmonic, spherical.**) These differential equations occur in the quantum mechanical problems of the rigid rotator and the hydrogen atom.

LEGENDRE POLYNOMIAL. A solution of the **Legendre differential equation.** The as-

sociated polynomials may be defined by the expression

$$P_n^m(x) = (-1)^m(1 - x^2)^{m/2}\frac{d^mP_n(x)}{dx^m}$$

and the special case, $m = 0$, is the Legendre polynomial of degree n

$$P(x) = \frac{1}{2^n n!}\frac{d^n}{dx^n}(x^2 - 1)^n$$

$$= \frac{(2n)!}{2^n(n!)^2}\left[x^n - \frac{n(n-1)}{2(2n-1)}x^{n-2} + \frac{n(n-1)(n-2)(n-3)}{2.4(2n-1)(2n-3)}x^{n-4} \mp \cdots\right].$$

The first definition, in terms of the nth derivative, is called the **Rodrigues formula.** A second set of polynomials, linearly independent of P_n, is composed of polynomials of the second kind, Q_n. The general solution of the Legendre equation is then

$$y = AP_n(x) + BQ_n(x)$$

where A, B are arbitrary constants. Many other definitions and relations for these polynomials are known (See **Schläfli's formula, generating function, Heine formula.**)

LEIBNITZ RULE. A formula for the nth **derivative** of the product of two functions in terms of the successive derivatives of the factors:

$$\frac{d^n}{dx^n}(uv) = \frac{d^nu}{dx^n}\cdot v + \binom{n}{1}\frac{d^{n-1}u}{dx^{n-1}}\cdot\frac{dv}{dx} + \binom{n}{2}\frac{d^{n-2}u}{dx^{n-2}}\frac{d^2v}{dx^2} + \cdots + u\frac{d^nv}{dx^n}$$

$$= \sum_{k=0}^{n}\binom{n}{k}\frac{d^{n-k}u}{dx^{n-k}}\frac{d^kv}{dx^k}.$$

The coefficients are **binomial coefficients.**

LENARD RAYS. See **cathode rays.**

LENGTH. (1) The length of a straight line is the number of times that a specified measuring rod must be successively applied to cover the line completely.

(2) The length of a curve is equal to the length of a flexible, but inextensible, measuring rod which can be made to coincide exactly with the curve.

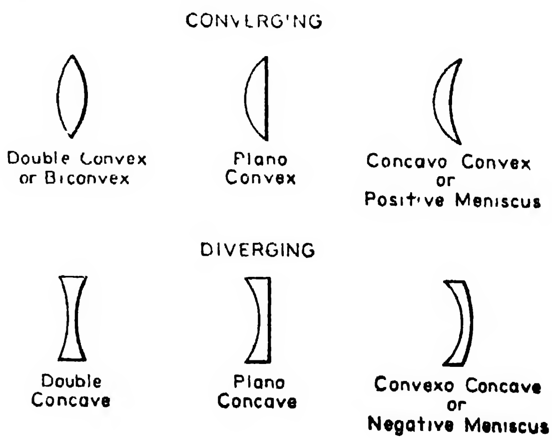
One of the three fundamental units in mechanics. (See also **mass,** and **time.**)

LENGTH OF PLATEAU. The voltage interval corresponding to the portion of the **plateau characteristic** in which a **Geiger-Muller counter tube** can be reliably operated.

LENGTH, UNITS OF. (1) Metric—The meter is the standardized unit. The common unit is the centimeter (cm) which is $\frac{1}{100}$ of a **meter.** Also used are the decimeter = 10 meters and the kilometer = 1000 meters. (2) English—The yard is the standardized unit. The common unit is the foot which is $\frac{1}{3}$ of a **yard.** Also used are the inch = $\frac{1}{36}$ of a yard and the mile = 5280 ft = 1760 yards.

LENNARD-JONES AND DEVONSHIRE THEORY. A theory of the liquid state which describes fusion as a dissociation of the **crystal lattice,** molecules moving from the lattice sites to inter-lattice holes. The **dissociation energy** decreases with thermal expansion and the theory gives a roughly quantitative description of fusion.

LENS. (1) An optical component consisting of one or more pieces of glass or other material transparent to the radiation being used, which has the surfaces so curved, ordinarily spherical, that radiation coming from an object will, after passing through the lens, form an image, real or virtual, of that object. A simple lens consists of a single piece of transparent material. Simple lenses may be of any of these forms:



In the double-convex and double-concave cases, the two curvatures may be alike, equiconvex or equiconcave, or they may be different.

(2) In communications, a structure transparent to radio waves, and with a relative **dielectric constant** different from unity, designed in such manner as to produce a desired pattern. Such structures may employ dielectrics or metallic configurations. (See **antenna lens; antenna lens, pathlength; antenna lens, dielectric; antenna lens, delay; antenna lens, metallic.**)

(3) In **electron optics**, a configuration of electric or magnetic fields arranged to produce the desired electron-beam pattern.

(4) A magnetic lens is an arrangement of coils and magnets so disposed that the resulting magnetic fields produce a focusing force on a beam of charged particles.

LENS, ACHROMATIC. A compound lens (see **lens, compound**) of at least two kinds of glass, which has the same focal length and the same magnification for light of two different wavelengths and nearly the same **focal length** for all intervening wavelengths. Certain thick lenses and certain compound lenses of a single sort of glass can be made achromatic, but such lenses are not commonly used. (See also **achromat.**)

LENS, APOCHROMAT. A compound lens (see **lens, compound**) constructed so that the **focal length** for three different wavelengths will be identical. This reduces **chromatic aberration** over a wider range of wavelengths than a simple achromatic lens which brings to identical focal length light of only two different wavelengths.

LENS, COATED. See **low-reflection films on glass.**

LENS COMBINATION, ZERO POWER. It is possible to introduce into an optical system a lens of zero power which makes no essential change in the **principal focal plane,** but which does reduce certain aberrations, particularly **coma.**

LENS, COMPOUND. The aberrations inherent to all single optical lenses can be reduced by constructing a compound lens of several simple lenses. These simple lenses are not ordinarily all of the same type of glass or other transparent material. (See **achromatic lens; apochromatic lens.**)

The simple lenses may be cemented together, or they may be separated by air spaces, or in the case of three or more elements, some may be cemented and others separated by air spaces.

LENS, CONVERGING. A lens (see **lens (1)**) with positive or **real focus** is called converging, since it causes light parallel to its axis to converge to a real focus.

LENS, CONVERTIBLE. A camera lens (see **lens (1)**) made up of two separable systems, each separately corrected so that either system or the total combined system may be used, thus giving greater flexibility of equipment.

LENS, CYLINDRICAL. A lens (see **lens (1)**) one surface of which is a portion of the surface of a cylinder. Cylindrical lenses have many uses, but the most common is for correcting **astigmatism** in the eye. They may be either concave (negative) or convex (positive).

LENS DISK. In some older forms of mechanical television, the rotating **scanning disk.**

LENS, DIVERGING. A lens (see **lens (1)**) with a negative or **virtual focus** is called diverging because it causes light parallel to its axis to diverge, as if coming from a point which is the virtual focus of the lens.

LENS, ELECTRIC ELECTRON. A device which employs only electric fields to focus an **electron beam.** (See also **electron lens.**)

LENS, FIELD. An auxiliary lens (see **lens (1)**) used to focus light which has passed through one or more stages of a long optical system, before it passes to later stages.

LENS, MAGNETIC. An arrangement of coils, electromagnets, or magnets so disposed that the resulting magnetic fields produce a focusing force on a beam of charged particles. (See also **electron lens.**)

LENS, METALLIC. See **lens (2); antenna lens, metallic.**

LENS, MENISCUS. A lens (see **lens (1)**) whose two surfaces have curvatures of the same sign; convexo-concave or concavo-convex.

LENS POWER. See **power, lens.**

LENS SIGN CONVENTION. See **sign convention.**

LENS, SPHERICAL WAVES INCIDENT ON A THIN. See **waves, spherical, incident on a thin lens.**

LENS SYSTEM, CARDINAL POINTS OF. See **cardinal points of a lens system.**

LENS, THICK. No useful single completely accurate formula can be written giving full object-image relation in terms of the properties of the lens forming the image. Hence many formulas with varying degrees of approximation are used. A "thin" lens is a lens (see **lens (1)**) being used in a computation which neglects the actual thickness of the lens itself. A "thick" lens is a lens being used in a computation which takes into consideration the thickness of the lens itself. (See Robertson, *Introduction to Optics, Geometrical and Physical,* 4th ed., Chapters III and IV.)

LENS, THIN. Any lens (see **lens (1)**), the thickness of which may be neglected for the process under consideration, as is done in many approximate computations.

LENS, TORIC. A lens (see **lens (1)**), one surface of which is a portion of the surface of a torus (a surface generated by a circle rotating about an axis in its own plane, but not through the center of the circle). Widely used in spectacles.

LENS, WEAK. A lens in which the focal lengths are long compared with the extent of the lens field.

LENSES, ALTERNATE POSITIVE AND NEGATIVE. A method of focusing an **electron beam** by the use of a series of alternating converging and diverging lenses (see **lens (3)**) of equal strength.

LENSES, ELECTRIC, APERTURES AS. An **aperture** connecting regions of different potential gradients will distort the field in its vicinity. This distortion may be used to focus an **electron beam** passing through the aperture. (See also **electron lens.**)

LENSOMETER. An instrument designed for the measurement of the optical characteristics of spectacle **lenses.**

LENTICULAR PROCESS. A process of color photography in which minute semi-cylindrical lenses (lenticules) on the film base, in conjunction with a banded color filter on camera and projector lenses, act as an optical color-separation system for both analysis and synthesis. The lenticular process is thus essentially a screen method in which the screen is formed optically on the film during exposure.

LENZ LAW. A general law of **electromagnetic induction,** stated by H. F. E. Lenz in 1833. It points out that the **electromotive force** induced by the variation of **magnetic flux,** with reference to a conductor, in the manner discovered by Faraday, is always in such direction that, if it produces a current, the magnetic effect of that current opposes the flux variation responsible for both electromotive force and current. The effect known as magnetic damping depends upon this principle. A copper disk, when spun between the poles of a strong magnet, quickly comes to rest because of the opposing torque.

LEPTON. A particle of small mass. Included in this class are the **electron, positron, neutrino** and **antineutrino.**

LETHARGY, NEUTRON. The value of the lethargy of a neutron is, to within an additive constant, the negative of the natural logarithm of the energy of the neutron.

LEVEL. The difference of a quantity from an arbitrarily specified reference quantity. (1) In audio technique, the quantities of interest are often expressed in decibels, thus their difference is conveniently expressed as a ratio. Hence, level is widely regarded as the ratio of the magnitude of a quantity to an arbitrary reference magnitude. (2) In television, level is (a), signal amplitude measured in accordance with certain specified techniques (see *IRE Proceedings* **39,** May 1950); or (b), a specified position on an amplitude scale applied to a signal waveform, as the term is used in such definitions as reference white level and reference black level.

LEVEL ABOVE THRESHOLD (SENSATION LEVEL). Of a sound, the pressure level of the sound in decibels above its threshold of audibility (see **audibility, threshold of**) for the individual observer. Similar defini-

tions are used for the other psychophysical stimuli, such as light.

LEVEL INDICATOR. (1) A device or instrument which indicates liquid level height, as in a tank. (2) A device or instrument which indicates the amount of radiation (see **monitor**) present in the vicinity of the instrument. (3) A **V-U meter.**

LEVEL OF ENERGY. The value of an energy, as for example an electrostatic potential, thought of as measured vertically above some fixed origin. Not the same as **energy level.**

LEVEL WIDTH. A measure of the spread in excitation energy of an unstable state of a quantized system. In emission or absorption spectra, variations in the intrinsic line widths show that some energy levels in atomic or nuclear systems are broad and others are narrow. In nuclear physics, level widths have been observed chiefly in connection with neutron and charged-particle resonances, which are found to have non-uniform breadths in energy. The level width is related to the mean life of the level by the expression:

$$\Gamma = \hbar/\tau$$

where Γ is the level width, $\hbar$ is the Dirac h, and τ is the mean life. Level widths usually show themselves as the widths of resonance peaks observed when the cross section for the particular reaction is plotted as a function of the energy of the incident particle. The quantitative value of the level width is usually taken as the full width at half maximum of the resonance peak.

If a system at a given level has several alternate modes of disintegration, there is associated with each a partial level width proportional to the probability of disintegration by the particular mode. The total level width is the sum of the partial level widths.

LEVER. A simple **machine** consisting fundamentally of a rigid bar or body which can rotate about a rigid point of support or fulcrum. The application of a force to the bar will produce motion of a load on the bar in accordance with the principle of **torques.** The mechanical advantage is equal to ratio of the "arms" where an arm is the distance from point of application of force or load to the fulcrum.

LEVI-CIVITA TENSOR DENSITY.

$$\begin{aligned} \epsilon_{ijk} &= 0 \text{ for any two indices identical} \\ &= \pm 1 \text{ otherwise,} \end{aligned}$$

the sign depending on whether ijk form an even (+) or odd (−) permutation of the integers 1, 2, 3.

LEVOROTATORY. Capable of rotating the plane of **polarized light** in a counterclockwise direction.

LEYDEN JAR. A high-voltage, low-capacitance **capacitor** using a glass jar as the **dielectric.**

L-F. Abbreviation for low frequency.

L'HOSPITAL RULE. A method for evaluating an **indeterminate form.** Suppose $f(a) = \phi(a) = 0$, then

$$\lim_{x \to a} \frac{f(x)}{\phi(x)} = \lim_{x \to a} \frac{f'(x)}{\phi'(x)}.$$

If the first derivatives do not exist, continue the differentiation until one derivative does not vanish at $x = a$. Other indeterminate forms may also be evaluated by suitable modifications of this rule. (The spelling L'Hopital is also found.)

LIBRATION. In general terms, a quivering or swaying motion, applied more specifically to an oscillating rotary motion, as of the moon about its axis or of a molecule in a solid where it has insufficient energy to make complete free rotations

LID. A term often used to denote a **temperature inversion** in the atmosphere. Since the air in an inversion is stable, convectional currents cannot exist within it For this reason an inversion is called a "lid," since it prevents the air below and above it from mixing.

LIEBMANN EFFECT. Visual perception of contrasting forms, as on a printed page, is more difficult when the forms have the same **luminances** and differ in **chromaticity,** than in the converse case.

LIESEGANG RINGS. The formation of a banded precipitate by **ions** which react by diffusion through certain **gels.** Thus, for example, if silver nitrate is dissolved in a warm gelatin sol which is then allowed to set, and a drop of sodium dichromate solution is de-

posited on its surface, the resulting silver chromate precipitate will appear in the gel as a series of rings, with clear areas between them. Theories have been advanced to explain the formation of Liesegang rings based on the formation of nuclei in supersaturated solutions.

LIFE, HALF-. See **half-life.**

LIFE, MEAN. The average time during which an atom or other system exists in a particular form, e.g., the mean time between the appearance and disappearance (birth and death) of a particle. Five examples are: (1) The mean life of **mesons** before undergoing transformation. (2) The mean life of excited nuclei or atoms before losing their energy of **excitation.** (3) For a **radionuclide,** the mean life is the reciprocal of the **disintegration constant.** For branching decay, it is given by

$$\tau = \frac{1}{\lambda} = \frac{1}{\lambda_1 + \lambda_2 + \lambda_3 \cdots}$$

where $\lambda_1, \lambda_2, \lambda_3, \cdots$ are the partial disintegration constants for the various modes involved. (4) For a thermal neutron, the mean time interval between the instant when the neutron becomes thermal, and when it disappears from the reactor by absorption or leakage. For a homogeneous medium, the infinite and finite lifetimes refer to the lifetime in infinite- and given finite-sized regions of the medium (5) When excess **carriers** are injected into a **semiconductor,** they will eventually recombine with others of the opposite sign. Experiment shows that in the bulk material this mean life may be rather long, because the recombination process between **holes** and electrons requires the emission of a **photon** or **phonon.** The process is much enhanced at the surface, as shown by the **Suhl effect.**

LIFETIME. (1) The mean life (see **life, mean**). (2) The **half-life.**

LIFETIME, COMPARATIVE. The product of the **half-life** or half-period of a β-disintegrator and a function (commonly represented by the symbol f) which expresses the probability per unit time that a β-transition will occur in a given nucleus. The function f depends chiefly upon the **β-disintegration energy,** and to some extent, also upon the atomic number of the product nucleus. The use of the comparative lifetime values puts all the β-disintegrators on the same basis so far as the disintegration energies and atomic numbers are concerned, and these values are measures of the inherent forbiddenness of the β-transitions (See also **Fermi theory of β-decay.**)

LIFETIME, VOLUME. The average time interval between the generation and recombination of minority carriers (see **carrier, minority**) in a homogeneous **semiconductor.**

LIGASOID. A **colloidal** system, in which the dispersed particles (or the dispersed phase) are liquid, and the dispersion medium (or the continuous phase) is gaseous

LIGHT. This term properly refers to the range of **electromagnetic radiation** frequencies associated with **vision;** though the physicist is apt to think of more objective manifestations, such as **photovoltaic effects,** and sometimes even oversteps the limits of the visible range by calling **infra-red** or **ultraviolet** radiation, and even **x-rays,** "light" The wavelengths of visible light extend approximately from 1000 angstroms (extreme violet) to 7700 angstroms (extreme red) Compared with radiation as a whole, this is an extremely limited range.

LIGHT-BEAM PICKUP. A phonograph pickup in which a beam of light is a coupling element of the **transducer.**

LIGHT, CIRCULARLY-POLARIZED. See discussion under **light, elliptically-polarized.**

LIGHT CONE THROUGH AN EVENT. All events at position r, time t, relative to the event, where $r^2 = c^2t^2$.

LIGHT, CORPUSCULAR THEORY. An old theory that light consisted of particles (corpuscles) of a luminous flux, later superseded by a pure wave theory. Present day theory of light combines the properties of waves and of particles (quanta) into a single consistent **quantum theory** of light (electromagnetic radiation).

LIGHT, ELLIPTICALLY-POLARIZED Given a thin section of **double-refracting** crystal with the optic axis of the crystal parallel to the face of the section. If now a beam of plane-polarized light (see **light, plane-polarized**) is incident normally on a face of the section with the plane of vibration

of the incident beam making an angle A with the optic axis of the crystal, the beam will be divided into two components, the ordinary and the extraordinary, which travel with different speeds. Upon emergence, the two components will, in general, have different phases and will combine to form elliptically polarized light. If the retardation in phase corresponds to an even number of half-wavelengths difference in path, the ellipse will degenerate into a line parallel to the incident plane of vibration. If the retardation in phase corresponds to an odd number of half-wavelengths (a half-wave plate) the ellipse will be again a line, but will make an angle $2A$ with the plane of vibration of the incident light If the retardation corresponds to an odd number of quarter-wavelengths (quarter-wave plate) the emergent light will be elliptically polarized If in addition A is 45 degrees, circularly-polarized light results.

LIGHT, ENERGY OF. Light is a form of energy, and at a wavelength of 555 millimicrons, one watt of **radiant power** gives about 685 **lumens** of light **flux**.

LIGHT-FILTER FACTOR. Light filters absorb a part of the incident light and, therefore, transmit less than was present before filtration. In photography the quantity of light present determines the exposure given to the emulsion Every filter, therefore, has a filter factor that applies to conditions of use and is the increase in exposure necessary to compensate for the light absorbed by the filter. The filter factor is generally determined by the exposure increase necessary with the filter when photographing a neutral gray subject, such as a **gray scale.**

LIGHT FILTER. A homogeneous optical medium that is characterized by its absorption in certain regions of the spectrum. A filter is used to change or control the total or relative energy distribution of a beam of light. In photography a filter may be placed over the light source or in some part of the optical path traversed by the light in reaching the photographic emulsion, generally over the camera lens (See also **filter, interference.**)

LIGHT FLUX. Flow of radiant energy commonly measured in **lumens.**

LIGHT MODULATION. In facsimile, the production of a modulated carrier output from a phototube by periodically interrupting (at a carrier-frequency rate) the variable-intensity, light beam being transmitted from the scanned subject copy.

LIGHT MODULATOR. The combination of a source of light, an appropriate optical system, and a means for varying the resulting light beam (such as galvanometer or light valve), so that a **sound track** may be produced

LIGHT, MONOCHROMATIC. Light which consists of only one wavelength. Actually no light is absolutely monochromatic. The nearest approach is certain lines in the spectrum of mercury 198, excited in an electrodeless discharge tube Most so-called monochromatic light, e g, sodium light, is actually a narrow band of wavelengths.

LIGHT-NEGATIVE. Having negative conductivity, i e, decreasing in electrical conductivity under the action of light. Most **photoconductive** substances are light-positive

LIGHT, PLANE-POLARIZED. Light consists of electromagnetic waves with their electric and magnetic vectors constantly normal to the direction of propagation of the light If the electric vectors of all components of a light-beam lie in the same fixed plane, the light is said to be plane-polarized.

LIGHT-POSITIVE. Having a **photoconductivity** which increases with an increase of light.

LIGHT PRESSURE. See **radiation pressure.**

LIGHT, PROPAGATION OF. Light consists of transverse electromagnetic waves propagated through empty space with a velocity of about 2.99776×10^{10} cm/sec. The velocity in other media is this figure (velocity *in vacuo*) divided by the **index of refraction.**

LIGHT, QUANTUM THEORY OF. When light interacts with matter, the energy of the light appears to be concentrated in quanta called photons, each of which has an amount of energy equal to the frequency of the light multiplied by the Planck constant, 6.624×10^{-27} erg seconds.

LIGHT, REFLECTION OF. A light ray meeting a boundary between two media is ordinarily partly- or totally-reflected, so that the **angle of incidence** equals the **angle of**

reflection, and both angles lie in the same plane normal to the boundary surface.

LIGHT, REFRACTION OF. When a beam of light strikes a boundary between two transparent isotropic media, the direction of the beam will be changed according to the relationship:

$$n \sin \theta = n' \sin \theta'$$

where n is the index of refraction of the first medium and θ the angle of incidence, while n' is the index of refraction of the second medium and θ' is the angle of refraction. In the case that the boundary is not sharply defined, but rather consists of a gradual change in some property of the medium, as for example, between two layers of air at different temperatures, the same law holds for each infinitesimal change.

LIGHT SENSITIVE. Possessing **photoconductivity, photovoltaic,** or **photoelectric emission** effects.

LIGHT-SENSITIVE TUBE. See **phototube.**

LIGHT-SOURCE SCANNING. Synonym for **flying-spot scanning.**

LIGHT SOURCES, STANDARD. The standard sources adopted by the C.I.E. (International Commission on Illumination) in 1931 are:

(1) A gas filled lamp with a color temperature (see **temperature, color**) 2848°K.
(2) The above lamp with a specified Davis-Gibson liquid filter to convert its color temperature to 4800°K.
(3) The above lamp with a specified Davis-Gibson liquid filter to convert its color temperature to 6500°K.

In 1951, at Stockholm, the C.I.E. changed the definition of Source (1) to read: "A gas-filled tungsten-filament lamp, operated at a color temperature of 2854°K According to the International Temperature Scale of 1948." Earlier standards included the standard **candle,** the **Hefner amyl acetate lamp,** a **black body** at the temperature of the freezing point of platinum. A definite dilemma is caused by the impossibility of reconciling the desire to give heterochromatic photometry a thoroughly objective status since it is, in fact, basically subjective.

LIGHT-SPOT SCANNER. See **flying-spot scanner.**

LIGHT, TRANSMITTED. Light that has traveled through a medium without being absorbed.

LIGHT VALVE. A device whose light transmission can be made to vary in accordance with an externally applied electrical quantity, such as voltage, current, electric field, magnetic field, or an electron beam.

LIGHT, VELOCITY OF. See **light, propagation of.**

LIGHT, WAVE THEORY OF. Light is shown to have the properties of waves by the phenomena of **interference** and **diffraction.** This is not in contradiction to the **quantum theory** of light, but is a supplement to quantum theory.

LIGHTNING. The electrical condition of the earth's surface and of the atmosphere is quite different in stormy weather from its normal, fair-weather state Over a level stretch of country in fine weather, there is distributed a negative surface charge estimated at about 0.00027 electrostatic unit per sq cm or 0.0014 coulomb per sq mile. Above this, the electric **potential** of the atmosphere increases with elevation at the rate of about 100 volts per meter, the upper atmosphere being, apparently, positively charged. The earth, the atmosphere, and the **ionosphere** thus form a vast **condenser,** through the dielectric of which there is constant leakage because of ionization What maintains the charges against this leakage is not well understood.

LIMIT. A finite number s approached by a **sequence** $\{s_n\}$ if, for every positive number $\epsilon > 0$, there exists a number N such that $|s - s_n| < \epsilon$ for all $n < N$. The sequence is then said to **converge,** or symbolically,

$$s_n \rightarrow s; \quad n \rightarrow \infty \quad \text{or}$$

$$\lim_{n \to \infty} s_n = s.$$

If the limit does not exist, the sequence **diverges.**

LIMIT OF RESOLUTION, RAYLEIGH CRITERION. See **Rayleigh criterion of resolving power.**

LIMIT OF RESOLUTION (TELESCOPE). Using the **Rayleigh criterion** for the resolution of **diffraction** patterns, it can be shown that the limit of resolution of a telescope with circular **aperture** is given by

$$\theta = 1.220\lambda/a$$

where a is the diameter of the circular aperture, which limits the beam forming the primary image, λ is the wavelength of the light and θ is the minimum **angle of resolution** of the telescope.

LIMITED PROPORTIONALITY, REGION OF. The part of the characteristic curve of pulse size versus voltage in which the **gas amplification** depends on the number of ions produced in the initial ionizing event, and also on the voltage. Used in connection with **counters (1).**

LIMITED STABILITY (CONDITIONAL STABILITY). In communications, a property of a system characterized by **stability** when the input signal falls within a particular range, and by **instability** when the signal falls outside this range.

LIMITER. A **transducer** whose output is constant for all inputs above a critical value. A limiter may be used to remove amplitude modulation and transmit angle modulation (see **modulation, amplitude**; and **modulation, angle**). (2) In television, the last I-F stage (or two) in an F-M receiver. The purpose of this stage is to eliminate all amplitude distortion, or variation in the F-M signal.

LIMITER CIRCUIT. A circuit which provides **limiting.**

LIMITER, DOUBLE. Two **limiters** in cascade.

LIMITING. In communications, the action performed upon a signal by a **limiter.**

LIMITING CURVES. Any line on a **phase diagram,** or other graphical representation of the conditions of a system, at which two phases are coexistent. Usually these limiting curves are the plotted curves that separate phases.

LIMITING DENSITY. The value which the density of a gas approaches as its pressure-volume **relationship** approaches the constant value (at constant temperature) of an **ideal gas.**

LINDE METHOD. See **low temperature.**

LINDECK POTENTIOMETER. See **potentiometer, Lindeck.**

LINDEMANN ELECTROMETER. See **electrometer, Lindemann.**

LINE. (1) The path described by a moving point. If, as is generally meant, the line is straight, its equation in a plane and in rectangular coordinates is $Ax + By + C = 0$, which is a **degenerate conic.** Other forms of its equation are: (a) $y = mx + b$, where m is the slope and b the y-intercept; (b) $x/a + y/b = 1$, where a,b are the x,y-intercepts, respectively; (c) $y - y_1 = m(x - x_1)$, where (x_1,y_1) is a point on the line; (d) $(y - y_1)/(y_2 - y_1) = (x - x_1)/(x_2 - x_1)$, where (x_2, y_2) is another point on the line; (e) $x \cos \theta + y \sin \theta = p$, where the perpendicular from the origin to the line has length p and makes an angle θ with the X-axis.

If the straight line is located in a three-dimensional rectangular coordinate system, its equation may be taken as

$$(x - x_1)/\lambda = (y - y_1)/\mu = (z - z_1)/\nu$$

or

$$(x - x_1)/(x_2 - x_1) = (y - y_1)/(y_2 - y_1) = (z - z_1)/(z_2 - z_1),$$

where (x_1,y_1,z_1), (x_2,y_2,z_2) are points on the line and λ, μ, ν are its **direction cosines** or numbers proportional to them. A straight line in space is also determined by the equations of two planes intersecting to form the given line. (2) A system for transfer of electrical energy between two points of an **electric circuit.** (3) A horizontal **scanning-element** in a **facsimile** or **television** system.

LINE(S), ACTIVE. In television, in scanning an image, those lines that are responsible for imparting the information of the image. The beam is inactive when moving rapidly from right to left, or from the bottom of the picture to the top.

LINE-BALANCE CONVERTER. See **balun.**

LINE, DISSIPATIONLESS. An ideal **transmission line** with zero series resistance and zero shunt conductance.

LINE EQUALIZER. See **equalizer, line.**

LINE, FLAT. A non-resonant line. (See **line, non-resonant.**)

LINE FLYBACK. See **horizontal retrace.**

LINE, FORBIDDEN. A spectral line produced by a **forbidden transition.**

LINE FREQUENCY. See **frequency, line.**

LINE HYDROPHONE. See **hydrophone, line.**

LINE LEVEL. See **level** and **volume level.**

LINE, LOW-LOSS. A transmission line with small amounts of power dissipation per unit length.

LINE MICROPHONE. See **microphone, line.**

LINE, NON-RESONANT. A **transmission line** terminated at the receiving end by its **characteristic impedance.** In this state, **standing waves** do not exist on the line.

LINE OF FORCE (ELECTRIC FIELD). See **field, electric; field, magnetic;** and **fields of force.**

LINE(S) OF FORCE, THEOREMS OF. See **lines of induction; fields vector;** the **Gauss law.**

LINE(S) OF INDUCTION. The original concept attributing physical reality to **lines of force** led to speaking of lines of induction, whereas we now speak just of **induction,** but in engineering often use the **line** as a unit of measure. A line of flux is a **maxwell** (10^{-8} **weber**), the unit of flux in the **cgs system.**

LINE OF NODES. See **node.**

LINE PAD. In broadcasting, a resistance-attenuation **network,** or pad, which is inserted between the program amplifier and the **transmission line** to the transmitter. The purpose of this pad is to isolate the output of the **amplifier** from the impedance variations of the line.

LINE PAIR. In spectroscopy, an analytical line and the **internal standard** line with which it is compared.

LINE, PARALLEL-WIRE. A **transmission line** composed of two parallel wires.

LINE SPECTRUM. See **spectrum, line.**

LINE SQUALL. Extremely turbulent, roll-type, **squall** cloud usually found at the leading edge of **squall lines** associated with rapidly moving cold fronts.

LINE-STABILIZED OSCILLATOR. An **oscillator** whose frequency is controlled by **a** section of high **Q** transmission line.

LINE STRETCHER. A section of **wave-guide** whose physical length is variable.

LINE SYNCHRONIZING PULSE. In television, the horizontal **synchronizing signal.**

LINE WIDTH. A measure of the spread in wavelength (or energy) of radiation that is normally characterized by a single wavelength (or energy) value. In practice, the width is usually measured at one-half the maximum intensity of the line. (See **level width; Doppler broadening; line spectrum.**)

LINE WIDTH, MAGNETIC RESONANCE. In magnetic resonance experiments, the width of the absorption lines depends on the interactions of the spins with each other and with the crystal lattice. It may be measured by the random fluctuating magnetic field exerted on a spin by its neighbors, i.e., is of the order of

$$\Delta H = \mu/a^3$$

where μ is the magnetic moment of each spin and a is the interatomic spacing. In liquids, however, the motion of the molecules is so rapid that this effect averages out to nearly zero. The line width in **ferromagnetic resonance** is anomalously large.

LINE WIDTH, NOMINAL. In television, the reciprocal of the number of lines per unit length in the direction of line progression.

LINEAR. Given the quantities x_1, x_2, x_3, $\cdots$, x_n, a **linear combination** of them is $a_1x_1 + a_2x_2 + \cdots + a_nx_n$. The quantities x_i are **linearly dependent** provided that one of them is a linear combination of the others; otherwise, they are **linearly independent.** The test for such dependence may be made by means of the **Gram determinant** or the **Wronskian.** For other uses of linear see **equation, linear** and **transformation, linear.**

LINEAR ABSORPTION COEFFICIENT. See **absorption coefficient, linear.**

LINEAR ACCELERATOR (HANSEN). A device which accelerates electrons to high energies. A copper tube is divided into a number of sections by means of disks, with holes in the center, placed at increasing intervals along the tube. Pulsed oscillations of extremely high frequency are introduced, and the wavelength of a given phase is determined by the distance between the disks in the tube. Since these distances increase regularly, the wavelength, hence the **phase velocity,** also increases, the frequency remaining constant. Electrons entering the tube with the forward phase of the wave always remain in phase with the traveling wave and hence steadily increase in energy as they progress down the tube.

LINEAR ACCELERATOR (M.I.T.). A linear accelerator for the production of high energy electrons, similar to the Hansen type (See **linear accelerator (Hansen).**)

LINEAR ACCELERATOR (SLOAN AND LAWRENCE). A device for the production of high-energy positive ions. It consists essentially of a number of cylinders, of increasing length, arranged in a straight line, alternate cylinders being connected together to the terminals of a high frequency oscillator. In traversing the gap between cylinders, ions become accelerated, and if the length of the cylinders is such that the ions reach the next gap in phase with the high-frequency oscillations, the ions acquire additional energy each time they pass from one cylinder to the next.

LINEAR AMPLIFIER. A **pulse amplifier** in which the output pulse height is proportional to an input pulse height for a given pulse shape up to a point at which the amplifier overloads.

LINEAR ARRAY. See **array, linear.**

LINEAR DISTORTION. Any form of **distortion** which is independent of the amplitude of the signal.

LINEAR MAGNIFICATION. For each optical surface in a system, the linear size of the image, I_i, is to the linear size of the object, O_i, as is the distance of the image, Q_i, to the distance of the object, P_i. Then

$$I_i/O_i = Q_i/P_i = m_i.$$

The total linear magnification of the system is then the products of the magnifications of the parts.

LINEAR PASSIVE ELECTRIC NETWORK. See **network, linear passive electric.**

LINEAR POWER, AMPLIFIER. See **amplifier, linear power.**

LINEAR RANGE. See **range.**

LINEAR RECTIFIER. See **rectifier, linear.**

LINEAR TRANSDUCER. See **transducer, linear.**

LINEAR VARYING-PARAMETER NETWORK. A linear network (see **network, linear**) in which one or more parameters vary with time.

LINEAR VECTOR FUNCTION. See **vector function; dyadic.**

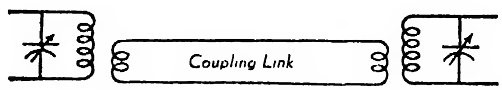
LINEARITY CONTROL. (1) In **cathode-ray tube equipment,** an adjustment that tends to correct any distortion in the sawtooth current or voltage waves used for deflection. (2) In television, a control which varies the distribution of **scanning speed** throughout the trace interval.

LINEARLY POLARIZED SOUND WAVE. See **sound wave, plane polarized.**

LINEARLY POLARIZED WAVE. See **wave, linearly polarized.**

LINGERING PERIOD. The length of time which an electron remains in its orbit of highest excitation (highest **energy level**) before jumping to a lower orbit, and radiating the difference in energy.

LINK COUPLING. A rather common system of inductive **coupling** used in radio transmitter circuits. The diagram is almost self-



Link-coupled tank circuits

explanatory, the primary circuit has a coupling winding of a few turns coupled to it, this being connected by a short transmission line to a similar coil inductively coupled to the second circuit. (See also **coupled circuits.**)

LINK MECHANISM. A system of rigid members joined together with constraints such that motion can be both amplified and changed in direction.

LINK NEUTRALIZATION. Neutralization accomplished in tuned, **radio-frequency amplifiers** by employing a pair of coupling links to feed energy from the output to the input.

LINKAGE. The bond used in constitutional formulas to represent one **valency.** Double and triple linkings refer to double and triple bonds. See the various terms under **bond** for definitions of many types of linkages, and their descriptions in terms of conceptions of molecular structure.

LINKAGE, CATENARY. The linking of molecules to one another end to end, as occurs when **amino acids** unite to form polypeptides.

LINKAGE, SINGLET. A valence **bond** between two atoms which consists of a single electron. This linkage can exist only under rather exceptional circumstances, as where the electron may resonate between a position close to one atom and one close to the other, and this condition would require little, if any, difference in energy between its two positions.

LIOUVILLE-NEUMANN SERIES. An infinite series

$$\phi(x) = \sum_{n=0}^{\infty} \lambda^n \phi_n(x),$$

which is a unique, continuous solution of a **Fredholm integral equation** of the second kind. If the nth iterated **kernel** is defined as

$$K_n(x,z) = \iint \cdots \int K(x,y_1)K(y_1,y_2) \cdots K(y_{n-1},z)dy_1dy_2 \cdots dy_{n-1},$$

then

$$\phi_n(x) = \int K_n(x,z)f(z)dz.$$

The resolvent or solving kernel is given by

$$K(x,z;\lambda) = \sum_{n=0}^{\infty} \lambda^n K_{n+1}(x,z)$$

hence the solution of the integral equation becomes

$$\phi(x) = f(x) + \lambda \int K(x,z;\lambda)f(z)dz.$$

The **Volterra equations** are solved similarly.

LIOUVILLE THEOREM. (1) If $f(z)$, a function of the **complex variable,** has no **singular point** for z finite or infinite, then $f(z)$ is a **constant.** (2) A theorem more familiar to the physicist and known by the same name occurs in statistical mechanics, and states that all elements of equal volume in phase space have equal *a priori* probabilities. This statement is a consequence of the ergodic hypothesis.

LIP MICROPHONE. See **microphone, lip.**

LIPPICH PRISM. See **prism, Lippich.**

LIPPMANN FRINGES. A film of special fine-grained photographic emulsion is backed by mercury, which serves as a reflector. Monochromatic light falling normally upon the film and reflected by the mercury gives rise to interference in **stationary waves** whose **nodes** and **antinodes** are in planes parallel to the reflector. At the antinodes the photographic action is a maximum, while at the nodes there is none. Hence when the film is developed the silver deposits in layers corresponding to the antinodes, one-half wavelength apart. The laminar structure, therefore, depends upon the color of the light.

LIQUEFACTION. Transformation (phase change) to the liquid state; commonly, the change from the gaseous to the liquid state, particularly of substances that are gaseous at normal temperatures and pressures.

LIQUEFACTION OF GASES. See **low temperature.**

LIQUID. Matter in a fluid state but relatively incompressible. An ideal liquid offers no permanent resistance to a shear stress but is incompressible. It has then a constant volume and incompletely fills any container of less than this volume. A real liquid is appreciably compressible, and the liquid state of a substance might be defined as the denser, and less compressible, phase of the two-phase fluid system which can exist in equilibrium at temperatures below the **critical temperature.**

LIQUID AS AN IMPERFECT GAS. Particularly at temperatures near the critical temperature, it is possible to regard a liquid as essentially a gas whose molecules have a finite volume and attract one another The molecules are in no way ordered, and the **equation of state** resembles the **van der Waal equation.**

LIQUID AS AN IMPERFECT SOLID. Particularly in the neighborhood of the melting-point, the arrangement of molecules in a liquid shows a degree of **short-range order.** In these conditions, shear flow of the liquid resembles closely the high temperature creep of crystalline solids. A number of theories of the liquid state have this concept as their starting point.

LIQUID, ASSOCIATED. A liquid containing **associated** molecules, as water is believed to contain associated groups such as $(H_2O)_2$, etc, due possibly to the formation of hydrogen bonds between H_2O molecules. **Polar liquids** associate readily.

LIQUID, COMPLEX. A liquid in which the rate of shear is not simply a linear function of the shearing stress. The simplest form of a complex liquid is probably a Maxwellian fluid (see **fluid, Maxwellian**) which behaves elastically for stresses of short duration but viscously for stresses of long duration.

LIQUID CRYSTALS. A term applied by Lehmann to liquids which are doubly-refracting and in which give **interference patterns** in polarized light An example is the turbid liquid formed on melting cholesteryl benzoate. Solutions of other large organic molecules also exhibit **birefringence,** particularly those parts of the solution near the walls or those undergoing shear. This effect is due to the tendency of the solute molecules to assemble in large "swarms," all oriented parallel to one another, and so leading to an anisotropic behavior. When there is a **velocity gradient** with lamellar flow, and in layers of the liquid of the same order as the chain lengths, this anisotropy is most pronounced. The **long-range order** is one of orientation only. (See also **mesomorphic state.**)

LIQUID-DROP NUCLEAR MODEL. A hypothesis due to Bohr and Wheeler in which the fission of an atomic nucleus is treated by analogy with the deformation and splitting of a liquid drop.

LIQUID, "KINETIC THEORY" ELASTICITY OF. See **"kinetic theory" elasticity of liquid.**

LIQUID JUNCTION. To avoid the unknown **liquid junction potential** in measuring the potential of a half-cell against a reference electrode, the two half-cells are frequently connected via a salt bridge, usually a concentrated solution of potassium chloride Since its anion and cation have almost the same velocity, a negligible diffusion potential is set up across the liquid junctions at the ends of the bridge.

LIQUID JUNCTION POTENTIAL OR DIFFUSION POTENTIAL. The potential difference across the boundary between aqueous solutions of an **electrolyte** at different concentrations, or between aqueous solutions of different electrolytes.

LIQUID, NORMAL. Also called a nonpolar or nonassociated liquid It is a liquid in which the molecules do not aggregate or form coordinate **bonds.**

LIQUID, POLAR. A liquid whose molecules have **dipole** moments.

LIQUIDS, INTERMOLECULAR DISTANCE IN. Although ordinary liquids expand on melting, the increase in volume is due not so much to an increase in the separation of a molecule from its nearest neighbors as to a decrease in the number of its nearest neighbors. The distribution of intermolecular distance may be specified by the **radial distribution function.** At higher temperatures, **short range order** disappears and intermolecular distances do increase.

LIQUIDS, LOOSE PACKING IN. The concept of a liquid as an imperfect crystal requires that the molecules in a liquid are packed sufficiently loosely for comparatively free movement, i.e., the energy required to move a molecule from a **lattice site** to a vacant space is not large compared with thermal energies.

LIQUIDS, SHORT RANGE ORDER IN. At temperatures not far removed from the melting-point, the crystalline structure of the solid persists over volumes comparable with

the intermolecular distances, but cannot be traced beyond. This local or **short-range order** means that the average molecule is at any moment surrounded by a number of molecules occupying nearly the same relative positions as they would in the solid state. The degree of short-range order is described by the **radial distribution function.**

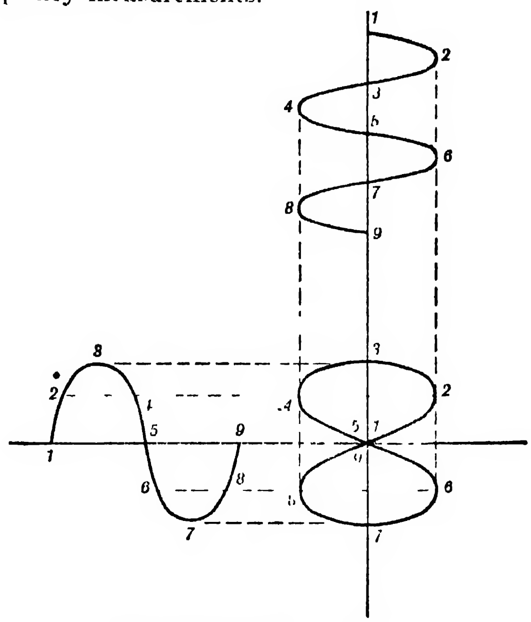
LIQUIDS, STRUCTURE OF. **X-ray diffraction** experiments show that, near the melting-point, the molecules of a liquid show a considerable degree of **short-range order** and that, in small volumes, they are arranged much as in a solid **crystal.** In larger volumes the order is less evident and the liquid is sometimes seen as a collection of molecular **clusters,** each being a small imperfect crystal. The volume of the liquid in this state does not greatly exceed that of the solid, the extra volume being required to provide vacant sites in the lattice which permit free flow. At much higher temperatures and lower densities, the short range order disappears, and the liquid may be treated as a highly condensed gas.

LIQUIDUS CURVE. In a temperature-concentration diagram, the line connecting the temperatures at which fusion is just completed for the various compositions.

LISOLOID. A **colloidal** system made up of a liquid phase surrounded by a solid phase.

LISSAJOUS FIGURES. When two sine waves, varying about axes at right angles, are combined the resultant figure is no longer a sine wave but varies with the relative time phase of the waves and with their relative frequency. For example, if the waves have the same frequency the resultant is a straight line when they are in time phase (or 180° out of phase) and is an ellipse for all other values of phase position. For equal amplitudes of the original waves and 90° phase the ellipse is the special case of the circle. If the frequencies of the two waves are not the same the resultant becomes more complicated but gives a definite pattern whenever the frequencies are in the ratio of whole numbers to one another. The figure shows a graphical construction for a frequency ratio of 1:2.

Such figures are obtained when the resultant motion of two **simple harmonic motions** at right angles to each other is examined. The figures can be produced in a cathode-ray tube by supplying each deflection-circuit with harmonically-related voltages. The figures are used thus for phase and frequency measurements.



Construction of Lissajous figure

LITER. The unit of volume in the **metric system,** defined as the volume of one kilogram of water at 4°C, and one atmosphere pressure.

1 liter = 1000 milliliters
1 liter = 1000.028 cubic centimeters
1 liter = 33.82 fluid ounces.

LITER-ATMOSPHERE. A unit of **work** defined as the work done in raising a piston of one square decimeter area one decimeter in a cylinder against a pressure of one atmosphere.

1 liter-atmosphere = 24.25 gram calories.

LITTROW MOUNTING OF PRISM AND PLANE MIRROR. A plane mirror is mounted nearly normal to the radiation emerging from the dispersing prism in a **prism spectrometer,** so that the radiation having passed through the prism is reflected and passes again through the prism. The spectrum is scanned by rotating the Littrow mirror instead of the prism, as in some other mountings.

LITTROW PRISM. See **prism, Littrow.**

LITZ WIRE. Fine-stranded wire in which each strand is individually insulated. It has reduced **skin effect,** and thus lower resistance at radio frequencies than other forms of wire of equivalent size.

LIVE ROOM. A room which is characterized by an unusually small amount of sound absorption, or stated conversely, a room that has an appreciable **reverberation time.**

LLOYD MIRROR. Light from a **slit** is reflected at nearly the grazing angle from a plane mirror. An **interference** pattern is formed on a screen between the light thus reflected and light which passes directly from the slit to the screen For a screen in contact with the end of the mirror, very near the point of contact where the two light-paths are ever so nearly the same, an interference minimum is found indicating that a **phase reversal** has occurred in the reflected light

LLOYD MIRROR EFFECT IN ACOUSTICS. Destructive interference near an interface between a sound source located close to the interface and its effective image just beyond the interface.

LO. Abbreviation for **local oscillator.**

LOAD. (1) Any **force** which is supported by a body is called a load. The forces which in turn support the given body are called reactions. A concentrated load is a theoretical force having a contact area negligibly small compared with the area of the surface of the body upon which the force acts. A distributed load is one whose area of contact covers, wholly or partially, the area of the supporting surface of the body Distributed loads are uniform if the intensity is the same for each unit of area covered by the load. When this intensity varies, the distributed load is non-uniform. (2) In communications, the load is the **signal power** delivered by a **transducer,** or the element to which it is delivered. (3) In induction heating and dielectric heating usage, the material to be heated, or the **charge.**

LOAD, CAPACITATIVE. See **capacitative load.**

LOAD (DYNAMIC) CHARACTERISTIC (OF AN ELECTRON TUBE CONNECTED IN A SPECIFIED OPERATING CIRCUIT, AT A SPECIFIED FREQUENCY). A relation, usually represented by a graph, between the instantaneous value of a pair of variables such as **electrode voltage** and **electrode current,** when all direct, electrode supply-voltages are maintained constant.

LOAD CIRCUIT. (1) The complete circuit required to transfer power from a source, such as an **electron tube,** to a **load.** (2) In induction heating and dielectric heating usage, the network including leads connected to the output terminals of a generator. The load circuit consists of the coupling network and the load material at the proper position for heating.

LOAD CIRCUIT A-C SUPPLY VOLTAGE. The a-c voltage source, appearing in the output circuit of a **magnetic amplifier,** the function of which is to supply power to the load during conducting intervals of the cycle. In general, this voltage source is also the gate circuit a-c voltage source.

LOAD-CIRCUIT EFFICIENCY. (1) The ratio between useful power delivered by the **load circuit** to the **load** and the **load-(anode-) circuit power input.** (2) In **induction heating** and **dielectric heating** usage, the ratio of the power absorbed by the load to the power delivered at the generator output terminals

LOAD-CIRCUIT POWER INPUT. The power delivered to the **load circuit.** It is the product of the alternating component of the voltage across the load circuit, the alternating component of the current passing through it (both root-mean-square values), and the power factor associated with these two quantities.

LOAD COIL. In **induction heating** usage, an electric conductor which, when energized with alternating current, is adapted to deliver energy by induction to a **charge** to be heated.

LOAD IMPEDANCE. The **impedance** presented by the **load to a transducer.**

LOAD, INDUCTIVE. See **inductive load.**

LOAD LEADS. In **induction** and **dielectric heating** usage, the connections or transmission line between the power source or generator and **load, load coil** or **applicator.**

LOAD-LINE METHOD. A method applicable to the solution of many non-linear

circuit problems. As an example, the method will be used to evaluate the d-c plate voltage

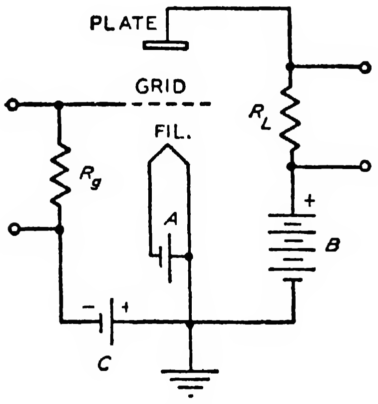


Fig 1 Triode amplifier circuit (By permission from "Electronics" by Williams, Copyright 1953, D Van Nostrand Co, Inc)

and current in the triode amplifier circuit shown in Figure 1. The voltage equation for the plate circuit is

$$E_{bb} = E_p + I_p R_L \quad \text{or} \quad E_p = E_{bb} - I_p R_L$$

If I_p is plotted against E_p as shown in Figure 2, the result will be a straight line with intercepts E_{bb} on the E-axis and E_{bb}/R_L on the I-axis. On the same graph characteristic curves I_p vs. E_p (E_g = constant) for the particular tube may also be constructed. The intersection of a given characteristic curve

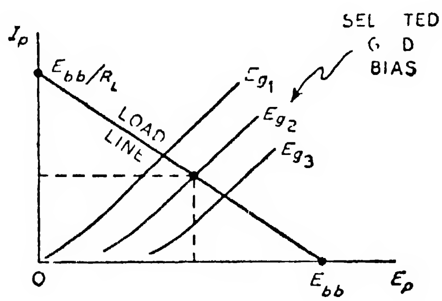


Fig. 2 Load-line method used to evaluate plate current and plate voltage for triode amplifier circuit (By permission from "Electronics" by Williams, Copyright 1953, D Van Nostrand Co, Inc)

and the straight line gives the **plate current** and **plate voltage** to be expected for a given **grid voltage.** The method will work equally well for other **vacuum tubes. phototubes, transistors, thermistors,** etc., where one set of circuit parameters are non-linear to the extent that they may only be expressed accurately by graphs.

LOAD MATCHING. (1) Maximum power is delivered to a **load** when the impedance of the generator is the **image impedance** of the load. The adjustment of a circuit to provide this condition is called load matching (2) In induction heating and dielectric heating usage, the process of adjustment of the **load circuit impedance** to produce the desired energy transfer from the power source to the load.

LOAD MATCHING NETWORK. In **induction** and **dielectric heating** usage, an electric network for accomplishing **load matching.**

LOAD MATCHING SWITCH. In **induction** and **dielectric heating** usage, a switch in the **load matching network** to alter its characteristics to compensate for some sudden change in the load characteristics, such as passing through the **Curie point.**

LOAD SWITCH (LOAD CONTACTOR). The switch or contactor in an **induction heating** circuit which connects the high-frequency generator or power source to the **load coil or load circuit.**

LOAD TRANSFER SWITCH. A switch to connect a generator or power source optionally to one or another **load circuit.**

LOAD WINDING. Synonym for **gate winding.**

LOADED APPLICATOR IMPEDANCE. In **dielectric heating** usage, the complex impedance measured at the point of application with the **load** material at the proper position for heating, at a specified frequency.

LOADED IMPEDANCE. See **impedance, loaded.**

LOADED MOTIONAL IMPEDANCE. See **impedance, motional.**

LOADING COIL. (1) An **inductance** inserted at regular intervals along a long **transmission line** or **cable** to increase the line's characteristic impedance (see **impedance, characteristic**) and reduce its **attenuation constant.** (2) An inductance inserted in series with an antenna to increase its **electrical length.**

LOBE, MAJOR (BEAM). The **radiation lobe** containing the direction of maximum radiation.

LOBE, MINOR. Any lobe except the **major lobe.**

LOBE SWITCHING. A form of **scanning** in which the direction of maximum radiation is switched periodically through two or more directions.

LOCAL CONTROL. See **control, local.**

LOCAL OSCILLATOR. The **oscillator** in a **superheterodyne receiver** which supplies the frequency to the **mixer** necessary to **heterodyne** the original signal frequency down to the desired **intermediate frequency.** The elements for this oscillator may be in the same **envelope** as the mixer.

LOCALIZATION. The identification of the apparent direction of a sound source by means of **binaural effects.**

LOCKED GROOVE. See **eccentric groove.**

LOCK-IN AMPLIFIER. See **detector, synchronous.**

LOCKOVER CIRCUIT. Colloquialism for a **bistable circuit.**

LOCTAL BASE. See **loktal base.**

LOCUS. A system of points, lines, or curves satisfying given conditions. The **locus** of an equation is thus the set of all points which satisfy the equation.

LOGARITHM. If B is an arbitrarily chosen number greater than unity, then the **logarithm** L of any other number N is defined by $N = B^L$; $L = \log_B N$. The chosen number B is the **base** of the system of logarithms. For any base, $\log_B 1 = 0$; $\log_B B = 1$. The fundamental properties of logarithms are

$$\log ab = \log a + \log b;$$

$$\log a/b = \log a - \log b;$$

$$\log a^n = n \log a$$

where a, b are positive numbers and n may be greater than unity or less than unity (thus a power or a root of the number, rational or irrational). Two systems of logarithms are generally used. (See **logarithm, common** and **logarithm, natural.**)

LOGARITHM, COMMON. A system of **logarithms** to the base 10. Also called **Briggs logarithms,** they are particularly useful for numerical computation. The common logarithm of a number N could be indicated by $\log_{10} N$ but the notation $\log N$ is more usual. Since any number may be written in the form $N = 10^n \times M$, where n is an integer, positive or negative, its common logarithm is $\log N = n + \log M$. The first part of this sum is the **characteristic** of the logarithm and it may be obtained by inspection of the given number. The second part, called the **mantissa,** is an irrational number, less than unity and usually given in decimal form. Tables of the mantissas of common logarithms are available with four, five, six, etc., significant figures so that any required accuracy can be obtained in numerical calculations.

LOGARITHM, NATURAL. A system of **logarithms** to the irrational base $e = 2.71828\cdots$. It is also called the **Napierian** or **hyperbolic system.** Such logarithms occur as the result of differentiation, integration, etc., and they often appear in equations representing physical phenomena but common logarithms are more convenient for numerical computation. Instead of the more exact symbol $\log_e N$, the abbreviated notation $\ln N$ is customary. The **modulus** of the common system relative to the natural system of logarithms is $\log e = 0.434294\cdots$ and, inversely the modulus of the natural system is $\ln 10 = 2.302585\cdots$. Conversion of one system of logarithms to another is made from the relations $\log N = 0.434294\cdots \ln N$; $\ln N = 2.302585\cdots \log N$.

LOGARITHMIC DECREMENT. For oscillations of a **dissipative system,** the logarithmic decrement is the logarithm to the base e of the ratio of two successive amplitudes. It is equal to $(R/2m)T$ where R is the damping coefficient, m, the mass, T, the period of free oscillations, A_1, A_2 are successive amplitudes (A_2 the later). The logarithmic decrement is also used in other than mechanical systems (See **damped oscillation.**)

$$\log_e \frac{A_1}{A_2} = \frac{R}{2m} T.$$

This is sometimes called simply the decrement.

LOGARITHMIC DECREMENT OF CIRCUIT. See **circuit, logarithmic decrement of.**

LOGARITHMIC DIFFERENTIATION. Sometimes a **derivative** is found most easily by taking **logarithms** on both sides of the defining functional equation and then differentiating. The result of logarithmic differentiation is $d \ln f = df/f$

LOGARITHMIC ENERGY DECREMENT. The mean value of the increase in **lethargy** per collision.

LOKTAL BASE. An eight-pin tube-base having pins which extend directly through the tube's **envelope.** Its most distinctive feature is the metallic, center guide-post which is designed to lock the base tightly in place when placed in an appropriate socket.

LOKTAL TUBE. An **electron tube** with a **loktal base.**

LONDON DIPOLE THEORY. A theory that accounts for the attractive forces between molecules by considering the interactions between the instantaneous **dipole moments** of the molecules. By considering the first order perturbation, it is shown that the interaction energy varies inversely as the sixth power of the distance between the molecules. (See **London forces.**)

LONDON EQUATIONS. Modifications of the equations of electrodynamics to describe the phenomena of **superconductivity.** They may be written

$$\mathbf{E} = \Lambda \frac{d\mathbf{j}}{dt}\ ; \quad c \operatorname{curl} \Lambda\mathbf{j} = -\mathbf{H}$$

where $\mathbf{E}$ and $\mathbf{H}$ are the macroscopic electric and magnetic fields, $\mathbf{j}$ is the electric current vector, and $\Lambda = m/ne^2$, n being the number of superconducting electrons per unit volume. (m, e, mass and charge of electron, c, velocity of light).

LONDON FORCES. Forces due to mutual perturbations of the electron clouds of two atoms or molecules which, when the molecules are in their **ground electronic states**, are always attractive. The principal part of these forces is due to interactions between the instantaneous **dipole moments** and gives a potential energy varying inversely as the sixth power of the molecular separation. (See also **van der Waals forces.**)

LONG-LINE EFFECT. When an **oscillator** is tightly coupled to a **load** through a **transmission line** which is very long in comparison with its wavelength, erratic operation may occur. • The oscillator **admittance,** plus the admittance of the long line and load, may cause several frequencies to be equally suitable for oscillation. Therefore, when the oscillator is operating at one frequency, and is loaded at this frequency, it may jump to a nearby frequency where its power output will be less. The oscillator may be said to be frequency-sensitive.

LONG RANGE ORDER. A system may be said to possess long range order if it is possible to assign letters A, B, C, etc. to the sites of the lattice in such a way that there is a greater probability of finding an atom of type A on an A-site, of type B on a B-site, and so on, than any other arrangement. Such order is characteristic of **order-disorder transitions** in **binary alloys.** It is measured by the parameter

$$S = \frac{r - w}{r + w}$$

where r and w are the numbers of atoms on right and wrong sites respectively.

LONG-WIRE ANTENNA. See **antenna, harmonic.**

LONGITUDINAL CHROMATIC ABERRATION. A measure of **chromatic aberration** equal to the distance between the **focal points** for red light and violet light.

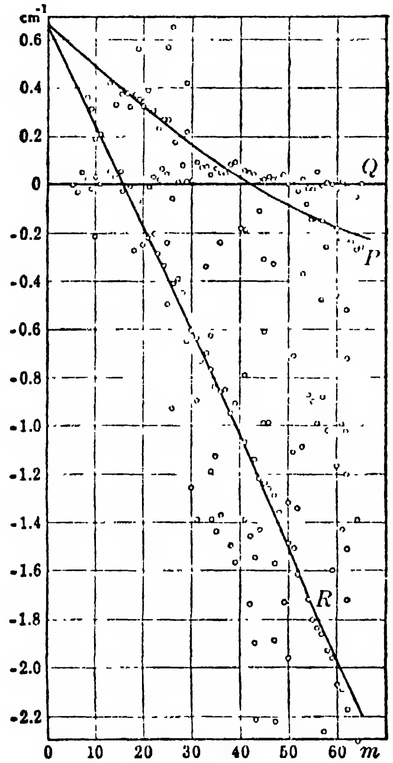
LONGITUDINAL MAGNIFICATION. **Linear magnification** measured parallel to the optical axis. If dx is measured parallel to the optical axis in object space and dx' is its conjugate distance in image space, then dx'/dx is the longitudinal magnification.

LONGITUDINAL SPHERICAL ABERRATION. The difference between the **focal length** of **rim rays** and **paraxial rays.** (See also **lateral spherical aberration.**)

LONGITUDINAL WAVE. See **wave, longitudinal.**

LOOMING. A type of **mirage** in which images of objects below the horizon appear in distorted form.

LOOMIS-WOOD DIAGRAM. A graph used in the identification of branches in electronic band systems of optical spectra. This method is especially useful where the individual bands of a band system lie so close to one another that their fine structures overlap considerably, or where multiplet bands are involved, with their large number of branches. The plot shown in the diagram is made as follows: Let us assume that by inspection of the

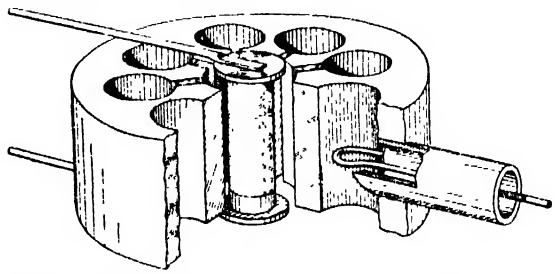


Loomis-Wood Diagram of the 1-1 band of the blue-green system of Na_2 (By permission from "Molecular Spectra and Molecular Structure I. Spectra of Diatomic Molecules," 2nd Ed. by Herzberg, Copyright 1950, D. Van Nostrand Co., Inc.)

spectrogram a few lines have been found that apparently belong to one and the same branch. We then form the first and second differences for this "branch," and, keeping the second difference constant, we calculate the expected positions of further lines on both sides of the observed part of this branch. We then have a series of wave-number values that might represent a branch. For each line of this calculated branch we now form the differences with all the neighboring observed wave numbers and plot them in a diagram against the arbitrary running numbers in the branch. We obtain a diagram such as that shown in the figure for the case of an Na_2 band.

LOOP, ANTENNA. See **antenna loop.**

LOOP, CENTER-COUPLED. A **coupling loop** in a **multi-cavity magnetron** which is located in the center of one of the resonant cavities of the tube.



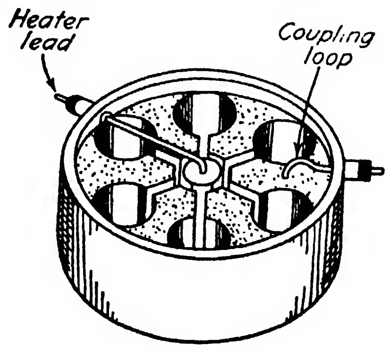
Center-coupled loop output (Courtesy Bell System Technical Journal)

LOOP GAIN. In feedback terminology, the gain around the **feedback loop,** numerically equal to the product of the **forward gain** by the gain of the **feedback network.** (The feedback network is also called the β-network.)

LOOP, HALO-COUPLED. A **coupling loop** in a multi-cavity **magnetron** which is mounted in the end space, close to one end of one of the resonant cavities of the tube.

LOOP, PROGRAM. A **transmission line** carrying broadcast program material from one point or station to another.

LOOP, SEGMENT-FED. A **coupling loop** in a multi-cavity magnetron, similar to a halo-coupled loop, in which one end of the



Segment-fed loop coupler (By permission from "Microwave Theory and Techniques" by Reich et al., Copyright 1953, D. Van Nostrand Co., Inc.)

loop terminates on the end of one of the segments between the resonant cavities. (See **loop, halo-coupled.**)

LOOP (STANDING WAVE). Interference between two trains of waves (light, sound, etc.) moving in opposite directions with equal speeds and frequencies, may cause points of no disturbance, nodes; the region between two nodes is a loop, or **antinode.**

LOOPSTICK ANTENNA. See **antenna, loopstick.**

LORAN. The word loran is derived from the phrase long-range navigation and is used to indicate the system of hyperbolic navigation which has the longest range of all systems thus far developed. Loran signals are of the pulse type and, in the progress of the developmental research, many different combinations of radio frequencies and pulse rates were used. One of the systems developed is known as Standard Loran and is used in commercial air and sea navigation. Since loran is a hyperbolic system, the stations must operate in pairs as "master and slave." The slave station is essentially a relay station.

The time systems of the master and slave stations are such that the signal from the master always reaches a ship during the first half of the recurrence cycle, and that from the slave during the second half. This is accomplished by including a delay circuit in the slave timing system that delays the retransmission of the signal received from the master until half the recurrence period has elapsed. (See Fig. 1(a) and (b).)

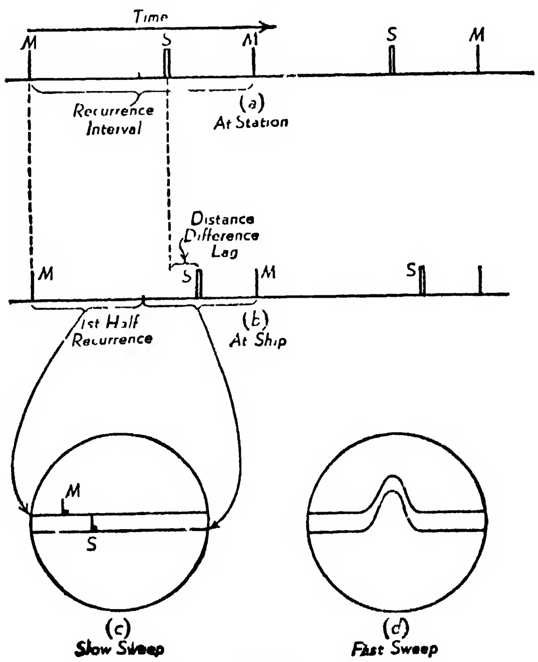


Fig. 1

Standard receiving equipment has been designed for ships and planes in which both the receiving and timing units are present, with selector switches permitting the operator to set on the frequency and recurrence rate assigned to any loran pair he wishes to use. Differential amplifiers, synchronized by the timing circuit to the recurrence rate of the station, act on both the master and slave signals to deliver them at equal strength to the indicator unit. The slow sweep of the oscilloscope ("viewing scope") appears as two parallel lines, one covering the first half of the recurrence cycle and the other the second half. Hence the signals received from the master appear on one line and from the slave on the adjacent parallel line. (See Fig. 1(c).)

When the signals are properly "set up" on the scope, a set of time markers is thrown on the screen and a determination is made of the time interval between reception of signals from the master and slave. This will include the delay interval at the slave station, but, since this is standard for each recurrence rate, it may be allowed for. A delay circuit is now introduced and the signals brought into approximate coincidence. With this adjustment made, a fast sweep spreads out the signals so that close coincidence may be established (see Fig. 1(d)) and the time interval measured to within one microsecond. Using this measured difference in time of arrival of the two signals the navigator then uses either tables or loran charts to obtain one line of position. The selector switches are then set to the characteristics of another loran pair, a second line of position determined, and a fix obtained. (See Fig. 2.) The time required to obtain such a

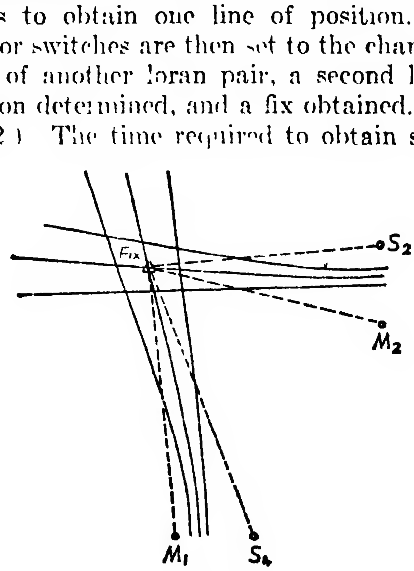


Fig. 2

fix is between 2 and 3 min. The accuracy of the determined fix is of the same order of magnitude as that obtained from good celestial navigation and, of course, is independent of the state of visibility.

LORENTZ CONDITION. The condition

$$\nabla \cdot \mathbf{A} + \frac{1}{c}\frac{\partial \phi}{\partial t} = 0$$

which may be imposed on the **vector** and **scalar potentials** describing an electromagnetic field. In **Minkowski space** the condition may be written

$$\frac{\partial A_\mu}{\partial x_\mu} = 0.$$

LORENTZ CONTRACTION. See **Fitzgerald factor.**

LORENTZ DOUBLE REFRACTION. A group of optical, second-order, **double-refraction** effects even in certain cubic crystals, which are not ordinarily observed and not included in the usual theories of crystal optics.

LORENTZ EQUATION OF MOTION. The equation describing the classical motion of a particle of charge e, rest mass m_0 in an external electromagnetic field $f_{\mu\nu}$:

$$\frac{d^2 x_\mu}{ds^2} = \frac{e}{m_0 c^2} f_{\mu\nu} \frac{dx_\nu}{ds},$$

(Gaussian units).

LORENTZ FACTOR. The number $4\pi/3$ by which the **polarization** must be multiplied in order to obtain the **Lorentz field.**

LORENTZ FIELD. The fictitious field introduced in the theory of dielectric and magnetic polarization in order to find the actual local field acting on the molecules. It is defined as the field produced inside a spherical cavity in a uniformly polarized medium, and has the value $(4\pi/3)P$ where P is the **polarization** of the medium.

LORENTZ FRAME. Any of the set of coordinate systems in **Minkowski space** for which the square of the interval between two events is $c^2dt^2 - (dr)^2$. Any such coordinate system may be obtained from another by means of a **Lorentz transformation** (together, perhaps, with an orthogonal transformation of the space axes). With each Lorentz frame may be associated a **point observer,** each of whom moves with constant velocity relative to the others.

LORENTZ-LORENZ RELATION FOR DIELECTRIC CONSTANT. The variation of specific inductive capacity ϵ with density is given by the relation

$$\tau = \frac{\epsilon - 1}{\epsilon + 2}\frac{1}{\rho},$$

where ρ is the density and τ is a constant characteristic of the substance. The relation is not accurate for polar molecules and high densities.

LORENTZ NUMBER. The ratio

$$L = K/\sigma T$$

where K is the **thermal conductivity** and σ the **electrical conductivity** of a metal at absolute temperature T. This ratio was observed to be nearly constant for many metals by Wiedemann and Franz, in agreement with the **free electron theory of metals** which predicts the value

$$L = \frac{\pi^2}{3}\left(\frac{k}{e}\right)^2 = 2.7 \times 10^{-13}\ \text{statvolt}^2/\text{deg}^2$$

where k is **Boltzmann's constant** and e the electronic charge. This constancy is not maintained down to low temperatures, at least until the regime of **residual resistance** is attained.

LORENTZ THEORY OF THE ELECTRON. Model of the electron as a spherical ball of charge which contracts by the **Fitzgerald factor** in its motion through the ether (1895). Later reinterpreted according to special relativity theory (see **relativity theory, special**). Yields a rest mass of $4/3c^2$ times the total energy.

LORENTZ TRANSFORMATION. Relations connecting the distance and time intervals between two events as measured from two **Lorentz frames.** If S' moves relative to S with velocity v in the x-direction and dx, dy, dz, dt denote position and time intervals between two events as measured by S and dx', dy', dz', dt' the corresponding quantities for S', then

$$dx' = \gamma(dx - vdt)$$

$$dy' = dy, dz' = dz$$

$$dt' = \gamma\left(dt - \frac{vdx}{c^2}\right)$$

$$\left[\gamma = \left(1 - \frac{v^2}{c^2}\right)^{-1/2}\right].$$

Originally developed by Voigt (1887) and rediscovered by Lorentz (1904) but interpreted according to the **ether hypothesis.** Shown by Einstein (1905) to be a consequence of special relativity theory.

LORENTZ TRANSFORMATION, PROPER. See **proper Lorentz transformation.**

LOSCHMIDT NUMBER. (1) The number of molecules in 1 cm^3 of an ideal gas at 0°C and 1 atmosphere, equal to 2.687×10^{19}. (2) In continental Europe, the term is sometimes used as synonymous with the **Avogadro constant.**

LOSS (TRANSMISSION LOSS). A general term used to denote a decrease in signal power in transmission from one point to another. Loss is usually expressed in **decibels.**

LOSS FACTOR. The rate at which heat is generated in a dielectric is proportional to its loss factor, which is equal to the product of its **dielectric constant** by its **power factor.** Both the dielectric constant and power factor are usually functions of frequency, therefore, the loss factor changes with changing frequency.

LOSS, INSERTION. See **insertion loss.**

LOSS MODULATION. Absorption modulation wherein the modulating voltage causes a variation in the energy absorbed from the carrier source.

"LOSSER." (1) A dielectric material which dissipates energy. (2) A **dissipative element** placed in a circuit to prevent **oscillation.**

"LOSSY." An adjective applied to a dielectric material which dissipates energy.

LOUDNESS. The intensive attribute of an auditory sensation in terms of which sounds may be ordered on a scale extending from soft to loud. Loudness depends primarily upon the **sound pressure** of the stimulus, but it also depends upon the frequency and wave form of the stimulus.

LOUDNESS CONTOURS. Curves which show the related values of **sound pressure level** and frequency required to produce a given **loudness** sensation for the typical listener.

LOUDNESS LEVEL. The loudness level, in **phons,** of a sound is numerically equal to the **sound pressure level** in decibels, relative to 0.0002 microbar, of a simple tone of frequency 1000 cycles per second which is judged by the listeners to be equivalent in loudness.

LOUDSPEAKER (SPEAKER). An electroacoustic transducer (see **transducer, electroacoustic**) usually intended to radiate acoustic power effectively at a distance in air.

LOUDSPEAKER, ACOUSTICAL LABYRINTH. A loudspeaker consisting of an absorbent walled conduit with one end tightly coupled to the back of the cone of a direct loudspeaker mechanism (see **loudspeaker, direct radiator**) and the other end opening in front or at the bottom of the cabinet within which it is folded.

LOUDSPEAKER, ACOUSTICAL PHASE-INVERTER. A loudspeaker consisting of a direct radiator loudspeaker mechanism (see **loudspeaker, direct radiator**) mounted in a completely closed cabinet save for a port coupling the cabinet volume to the air. The phase of the velocities on the two sides of the cone differs by 180°.

LOUDSPEAKER, CABINET. Any **loudspeaker** mounted in an open-back cabinet which also houses the radio or phonograph mechanism.

LOUDSPEAKER, COMBINATION HORN AND DIRECT RADIATOR. A loudspeaker consisting of a horn coupled to the back side of a direct radiator loudspeaker mechanism (see **loudspeaker, direct radiator**) and an acoustical capacitance for changing the output from the horn to the open side of the cone for reproduction of the mid- and high-frequency ranges.

LOUDSPEAKER, COMPRESSED AIR. A **loudspeaker** consisting of an electrically actuated valve which interrupts or **modulates** an air stream.

LOUDSPEAKER, CRYSTAL (PIEZOELECTRIC LOUDSPEAKER). A **loudspeaker** in which the mechanical **displacements are pro-**

duced by **piezoelectric** action. (See **bimorph cell.**)

LOUDSPEAKER, DIRECT RADIATOR. A **loudspeaker** in which the radiating element acts directly on the air.

LOUDSPEAKER, DIRECT RADIATOR DYNAMIC SUBAQUEOUS. A **loudspeaker** which contains a diaphragm driven by a **voice coil** located in a magnetic field and which is designed to operate under water.

LOUDSPEAKER DIVIDING NETWORK. See **network, dividing.**

LOUDSPEAKER, DOUBLE-COIL, DOUBLE-CONE. A loudspeaker consisting of a light coil coupled to a small cone, connected by a **compliace** to a heavy coil and large cone. An increase in range is obtained by reducing the impedance of both the coil and the diaphragm at the higher frequencies.

LOUDSPEAKER, DOUBLE-COIL, SINGLE-CONE. A **loudspeaker** consisting of a **voice coil,** divided into two parts separated by a **compliance,** coupled to a single corrugated cone. The inductance and electrical resistance of the larger portion of the voice coil is shunted by an electrical capacitance.

LOUDSPEAKER, DYNAMIC. A **loudspeaker** employing a cone driven by a current-carrying coil (the **voice coil**) in a constant magnetic field. The magnetic field may be supplied either by an electromagnet or a permanent magnet.

LOUDSPEAKER, ELECTROMAGNETIC. A dynamic loudspeaker (see **loudspeaker, dynamic**) in which an electromagnet provides the required magnetomotive force for the magnetic circuit.

LOUDSPEAKER, ELECTROSTATIC (CAPACITOR LOUDSPEAKER) (CONDENSER LOUDSPEAKER). A **loudspeaker** in which the mechanical forces are produced by the action of electrostatic fields.

LOUDSPEAKER, EXCITED FIELD. A **loudspeaker** in which the steady magnetic field is produced by an electromagnet.

LOUDSPEAKER AND MICROPHONE, H.F. DIRECT RADIATOR DYNAMIC SUBAQUEOUS. A direct radiator dynamic subaqueous loudspeaker with a smaller diaphragm and stiffer suspension system for use above 10 kc.

LOUDSPEAKER, HORN. A **loudspeaker** in which the radiating element is coupled to the medium by means of a horn.

LOUDSPEAKER, INDUCTION. A **loudspeaker** in which the current which reacts with the steady magnetic field is induced in the moving member.

LOUDSPEAKER, MAGNETIC ARMATURE (MAGNETIC LOUDSPEAKER). A **loudspeaker** comprising a ferromagnetic armature actuated by forces of magnetic attraction.

LOUDSPEAKER, MAGNETIC SUBAQUEOUS. A **loudspeaker** designed to operate under water, consisting of a resonant diaphragm driven by forces resulting from magnetic reactions.

LOUDSPEAKER, MAGNETOSTRICTION. A **loudspeaker** in which the mechanical displacement is derived from the deformation of a material having **magnetostrictive** properties.

LOUDSPEAKER, MAGNETOSTRICTION SUBAQUEOUS. A **loudspeaker,** designed to operate under water, in which a diaphragm is driven by the mechanical forces generated in a ferromagnetic rod possessing **magnetostrictive** properties.

LOUDSPEAKER, MOTIONAL ELECTRIC IMPEDANCE OF. The motional electric impedance of a single-coil, single cone-loudspeaker is given by $(Bl)^2/Z_{MT}$, where B = flux density in gauss, l = length of the conductor in the voice coil in air, Z_{MT} = total mechanical impedance of the mechanical system, in mechanical ohms.

LOUDSPEAKER, MOVING-COIL (DYNAMIC LOUDSPEAKER). A moving-conductor loudspeaker in which the moving conductor is in the form of a coil conductively connected to the source of electric energy.

LOUDSPEAKER, MOVING-CONDUCTOR. A **loudspeaker** in which the mechanical forces result from magnetic reactions between the fields of the current in a moving conductor and a steady magnetic field.

LOUDSPEAKER, MULTIPLE SINGLE-COIL SINGLE-CONE. Any of a number of loudspeaker systems consisting of a large-

diameter, heavy cone driven by a large **voice coil** for the low frequency range and a small diameter light cone and small voice coil for the high frequency range, and a **filter** system for allocating the power in the high and low frequency ranges to the respective low and high frequency units. Such systems are designed for uniform response, broad directional patterns and adequate power-handling capacity.

LOUDSPEAKER, PERMANENT MAGNET. A moving-conductor loudspeaker (see **loudspeaker, moving-conductor**) in which the steady field is produced by means of a permanent magnet.

LOUDSPEAKER, PNEUMATIC. A **loudspeaker** in which the acoustical output results from controlled variation of an air stream.

LOUDSPEAKER AND MICROPHONE, QUARTZ-CRYSTAL, SANDWICH SUBAQUEOUS. A subaqueous **transducer** consisting of two blocks of metal cemented to the two sides of a relatively thin, quartz crystal. One of the metal blocks is terminated in water and the other in air. Maximum output occurs when the overall effective length is one-half wavelength.

LOUDSPEAKER, QUARTZ-CRYSTAL, SUBAQUEOUS. A **loudspeaker,** designed to operate under water, in which a quartz crystal is driven by mechanical forces generated in the crystal due to converse **piezoelectric** properties.

LOUDSPEAKER, ROCHELLE - SALT, CRYSTAL SUBAQUEOUS. A **loudspeaker,** designed to operate under water, in which Rochelle-salt crystal is driven by mechanical forces generated in the crystal due to **piezoelectric** properties. This apparatus can also be used as a microphone, by means of the direct piezoelectric properties of the crystal.

LOUDSPEAKER, SINGLE-COIL DOUBLE-CONE. A **loudspeaker** consisting of a single coil coupled to two cones. In this system an increase in frequency range is obtained by reducing the mechanical impedance of the diaphragm by coupling a smaller cone to the **voice coil** at the high frequencies.

LOUDSPEAKER, SINGLE-COIL, SINGLE-CONE. A **loudspeaker** consisting of a cone driven by a **voice coil** located in a magnetic field.

LOUDSPEAKER SYSTEM. A combination of one or more **loudspeakers** and all associated baffles, horns, and dividing networks arranged to work together as a coupling means between the driving electric circuit and the acoustic medium.

LOUDSPEAKER VOICE COIL. The moving coil of a moving coil loudspeaker. (See **loudspeaker, moving-coil.**)

LOVIBOND TINTOMETER. A **colorimeter** in which the color of a solution or object is expressed in terms of glass slides of three colors. The instrument is equipped with a series of slides of each color, which are compared with the solution or object under examination.

LOW. A region over which atmospheric pressure is lower than the surrounding area; i.e., an abbreviation for region of low pressure. Cyclonic winds blow around a low.

LOW- AND HIGH-PASS FILTER. See **filter, band-elimination.**

LOW-LEVEL MODULATION. See **modulation, low-level.**

LOW-PASS FILTER. See **filter, low-pass.**

LOW-PRESSURE CLOUD CHAMBER. See **cloud chamber, low-pressure.**

LOW-REFLECTION FILMS ON GLASS. The action of these films depends jointly upon two different optical principles.

(1) Reflection of light occurs only at an interface between two different media. The ratio of the quantity of the light reflected by any reflector to that of the light incident upon it is called the reflection factor, or the reflectance, of that reflector. In the case of a glass surface covered with a transparent film, the reflection takes place partly at the outer surface of the film and partly at the interface between film and glass. It may be shown that the total reflectance of such a combination is a minimum when the absolute **refractive index** of the film is equal to the square root of that of the glass. Therefore it is desirable to find a film material which fulfills

this condition as nearly as possible and at the same time makes a durable coating adhering firmly to the glass. The materials which at present appear most satisfactory in these respects are calcium fluoride (CaF_2) and lithium fluoride (LiF). (2) All of the above remarks apply, irrespective of the thickness of the film If now the film be made of a thickness about one-quarter of the wavelength of the (normally) incident light, the reflectance is further reduced almost to zero by **interference.** The portions reflected by the film-glass interface and by the outer surface of the film are in such case in opposite phase to each other, and their effect is therefore subtractive instead of additive. It also follows that, since less light is reflected from glass provided with such films, more light is transmitted. This feature has proved of value in the treatment of lenses in optical instruments.

LOW TEMPERATURE MEASUREMENT. The platinum resistance thermometer can be used down to the temperature of liquid hydrogen. Below this lead resistance thermometers have been used, and also the rather insensitive constantan thermometer. In the temperature range of liquid helium, phosphor-bronze wire with small additions of a superconductor (usually lead) have been found useful. Carbon resistors provide useful resistance thermometers in the helium range, and at temperatures below 1°K. The most reliable thermometer in this range is provided by a paramagnetic salt whose susceptibility obeys the **Curie law.** Thermocouples are useful down to the temperature of liquid air.

LOW TEMPERATURE METHOD FOR LATENT HEAT OF VAPORIZATION. The liquid is evaporated under constant pressure out of a vacuum calorimeter, and the evaporated amount is measured by determining the volume and pressure of the gas at room temperature.

LOW TEMPERATURE PRODUCTION BY ADIABATIC DEMAGNETIZATION—NUCLEAR DEMAGNETIZATION. The interaction of the nuclear spins is weaker than that of the paramagnetic spins, so that they will remain largely disordered at temperatures accessible by paramagnetic demagnetization. Therefore, it has been proposed to use nuclear demagnetization to carry out demagnetization cooling reaching considerably lower temperatures than have been attained so far, even by methods as effective as that described in the next definition. (See also **adiabatic demagnetization, cooling by.**)

LOW TEMPERATURE PRODUCTION BY ADIABATIC DEMAGNETIZATION—TWO-STAGE DEMAGNETIZATION. A method of reaching temperatures of about one-thousandth of a degree absolute by carrying out two successive demagnetizations of paramagnetic salts in the same apparatus. The first stage consists of an ordinary demagnetization from the temperature of liquid helium A second sample of salt is cooled in a magnetic field to the final temperature of the first stage and subsequently demagnetized adiabatically.

LOW TEMPERATURE PRODUCTION BY CLAUDE METHOD. A method of gas liquefaction in which the cooling process is expansion with work being done in a reciprocating engine. In order to avoid formation of liquid in the cylinder, the last few degrees of cooling are usually covered by expansion without work.

LOW TEMPERATURE PRODUCTION BY LINDE METHOD. A method of gas liquefaction using the **Joule-Thomson effect** as cooling method. After expansion, the gas is returned to the compressor through a countercurrent heat exchanger in which the incoming compressed gas is cooled by the returning gas This process results in gradual cooling of the expansion valve until liquefaction occurs.

LOW TEMPERATURE PRODUCTION BY PICTET OR CASCADE PROCESS. A method by which a series of gases with successively-lower boiling points are liquefied. The first gas is liquefied under pressure, and then the temperature of the liquid is reduced by pumping off its vapor. The next gas, whose **critical point** must lie above the temperature reached by the first stage, is then liquefied under pressure and the process is repeated. It can only be continued as long as gases are available which have, in the liquid state, overlapping temperature intervals.

LOWEST USEFUL HIGH FREQUENCY. See **frequency, lowest useful high.**

LUMEN. The unit of **luminous flux.** It is equal to the flux through a unit solid angle (steradian) from a uniform point source of one **candle**; or to the flux on a unit surface all points of which are at unit distance from a uniform point source of one **candle.**

LUMEN-HOUR. A unit quantity of luminous energy equal to the emission of 1 **lumen** for one hour.

LUMEN METER, LUMETER. A device for measuring or comparing **luminosities.**

LUMERG. A unit of luminous energy (see **energy, luminous**). One erg of radiant energy having a luminous efficiency of x **lumens** per watt is x lumergs of luminous energy.

LUMINANCE. The quantitative attribute of light that correlates with the sensation of **brightness** and is the evaluation of radiance by means of the standard **luminosity function.** Units fall into two classes, (1) "intensity-luminance" defined by $B = I/(A \cos \theta)$ where I is the luminous intensity of the area A as viewed along a direction that makes an angle θ to the normal to the surface, and is measured in candles/meter^2, candles/ft^2, candles/cm^2, and a second set of units, (2) "lambert-luminance," where $B' = \pi B$, and is measured in meter-lamberts, ft-lamberts, cm-lamberts, etc.

LUMINANCE CHANNEL. In a color-television system, any path which is intended to carry the **luminance signal.** The luminance channel may also carry other signals; for example, the **carrier color signal,** which may or may not be used.

LUMINANCE SIGNAL. A signal wave which is intended to have exclusive control of the **luminance** of the picture in television.

LUMINESCENCE. Broadly, this term refers to the emission of light due to any other cause than high temperature. A firefly, for example, as well as certain fungi and many marine forms exhibit bioluminescence. Some electrolytic rectifiers are sources of galvano-luminescence. Triboluminescence is observed upon vigorously grinding certain solids, notably ordinary sugar. Thermal luminescence is shown by certain substances such as diamond, marble and fluorite which emit light at temperatures below a red heat. Photoluminescence is the emission of light as a result of nonluminous radiations.

A large variety of substances become luminescent when stimulated or "excited" by suitable radiation or by emissions such as **cathode rays** or **β-rays.** This phenomenon is apparently quite complex and is exhibited in various aspects. In some cases the light is emitted only so long as the exciting emission is maintained, it is called fluorescence. The screen of a fluoroscope thus responds to x-rays. In other cases the luminescence persists after the excitation is removed and it is then called phosphorescence. Thus zinc sulfide, under certain conditions, glows brightly for a time after exposure to daylight or lamplight, but the luminosity decays rapidly and disappears, usually within a few minutes. Some materials exhibit thermoluminescence; that is, they become luminescent, after exposure to excitation, upon being raised to a sufficiently high temperature. Resonance radiation may be regarded as a type of fluorescence in certain gases.

Stokes pointed out that when luminescence is excited by radiation, the frequency of the luminescence is usually less than that of the incident radiation. This is of course always true when visible luminescence is excited by ultraviolet rays, x-rays, or γ-rays.

Numerous theories regarding luminescence have been proposed They agree mostly in assuming that the emission of luminescence is due to the removal of electrons from molecules by the energy of the exciting rays, and the release of part or all of the energy upon their return. The **quantum theory** of radiation and electronic processes has done much in recent years to clarify certain aspects of the phenomena.

Materials which exhibit luminescence are known as **phosphors.**

LUMINOSITY. A general concept associated with the evaluation of **radiant power** by means of the standard **luminosity function.** Quantitatively it is the ratio of the **luminous flux** to the corresponding **radiant flux.** It is expressed in **lumens** per **watt.**

LUMINOSITY COEFFICIENTS. The constant multipliers for the respective **tristimulus values** of any color, such that the sum of the three products is the **luminance** of the color.

LUMINOSITY CURVE. A graphical relationship between wavelength of light in the visible range, and reciprocal of the **radiance** required to produce visual sensations of equal **brightness.** This reciprocal of required radiance or luminosity, is characteristic of the observer and conditions of observation.

LUMINOSITY CURVE, ABSOLUTE. A graphical relationship between wavelength of light and the **luminous efficiency** of radiant **flux,** expressed in **lumens** per watt. However, the absolute luminosity curve, like the **luminosity curve,** can be regarded as descriptions of a property of vision—the spectral sensitivity of the eye for brightness—as well as a property of radiant flux—its efficiency in affecting the eye. The absolute luminosity curve is found by multiplying the ordinates of the luminosity curve by 680, the value in lumens per watt of the maximum luminous efficiency of radiant flux of wavelength 555 millimicrons.

LUMINOSITY FUNCTION (STANDARD). Because of the variable sensitivity of the eye to radiation of different wavelengths, a standard function has been established by the Commission Internationale de l'Éclairage (CIE), formerly called in English translations International Commission on Illumination (ICI), for converting radiant energy into luminous (i.e., visible) energy.

For the standard conditions chosen in establishing this standard luminosity function (**photopic vision**) the luminously effective radiant intensity in lumens of radiation of spectral intensity J_λ watts/unit wavelength is given by

$$680 \int_{\lambda=0}^{\lambda-\infty} y_\lambda J_\lambda d_\lambda$$

where y_λ is the standard luminosity function normalized to a value of unity at 555 millimicrons. The numerical values for y_λ are commonly given as a **luminosity curve.**

For very low levels of intensity (**scoptopic vision**) the peak of the luminosity function curve shifts toward the violet for young eyes (507 mμ) with an absolute value of 1746 lumens/watt.

LUMINOSITY, RELATIVE. See **relative luminosity.**

LUMINOUS COEFFICIENT. A coefficient which measures the integrated fraction of the **radiant power** that contributes to its luminous properties as evaluated by means of the standard **luminosity function.**

Luminous coefficient

$$= \int_{\lambda=0}^{\lambda=\infty} y_\lambda J_\lambda d\lambda \Bigg/ \int_{\lambda=0}^{\lambda=\infty} J_\lambda d\lambda.$$

Where y_λ is the standard luminosity function and J_λ is the spectral power distribution of the radiant intensity. The luminous coefficient is unity for a narrow band of wavelengths at 555 millimicrons.

LUMINOUS EFFICIENCY. A measure of the **luminosity** per unit of radiant power, computed by multiplying the **luminosity coefficient** by the conversion factor 680 lumens per watt. This factor known as the maximum luminous efficiency, applies directly to radiant power confined to a narrow band of wavelengths at 555 millimicrons

LUMINOUS EMISSIVITY. See **emissivity.**

LUMINOUS EMITTANCE. See **emittance.**

LUMINOUS FLUX. The time rate of flow of light When **radiant flux** is evaluated with respect to its capacity to evoke the brightness attribute of visual sensation, it is called luminous flux, and this capacity is expressed in **lumens.**

LUMINOUS INTENSITY (IN ANY DIRECTION). The ratio of the **luminous flux** emitted by an element of a source, in an infinitesimal solid angle containing this direction, to the solid angle. Mathematically, a solid angle must have a point at its apex; the definition of luminous intensity, therefore, applie. strictly only to a point source In practice, however, light emanating from a source whose dimensions are negligible in comparison with the distance from which it is observed may be considered as coming from a point.

LUMINOUS REFLECTANCE, DIRECTIONAL. The ratio of the **luminance** of an imperfectly diffusing surface to the **illuminance** of a perfectly diffusing (and perfectly reflecting) surface.

LUMINOUS REFLECTANCE, SPECULAR. The ratio of (1) the **illuminance** of a surface observed by reflection in a mirror to (2) the **illuminance** of the surface seen directly in the specular luminous reflectance of the mirror.

LUMINOUS SENSITIVITY (OF A PHOTO-TUBE). The quotient of output current by incident **luminous flux** at constant electrode voltages. The term output current as here used does not include the **dark current.** Since luminous sensitivity is not an absolute characteristic but depends on the spectral distribution of the incident flux, the term is commonly used to designate the sensitivity to light from a tungsten-filament lamp operating at a color temperature of 2870°K.

LUMMER-BRODHUN CUBE. A **photometer** in which light from the standard source and the test source is reflected into an optical system of two prisms, so that the light from one source passes to the eye through the centers of the prisms, whereas the light from the other source is reflected to the eye from the part of the cube where the prisms are not in contact.

LUMMER-GEHREKE PLATE. A type of **interferometer** in which parallel beams of light produced by multiple reflection within a plate of glass may give interference of very high order. It is capable of very great resolution within a very narrow spectral range, but is now largely replaced by the **Fabry-Perot etalon.**

LUSTER. The reflection of the light from the surface of an object or material, and the appearance of the surface by that reflected light. The luster of minerals is a property which is useful in their identification. The luster of a mineral may be metallic, vitreous, adamantine, resinous, pearly, greasy, silky, dull, or earthy.

LUTECIUM. Rare earth metallic element. Symbol Lu. Atomic number 71.

LUX. The M.K.S. unit of **illuminance,** equal to one **lumen** meter^{-2}.

LUXEMBURG EFFECT. A type of atmospheric **cross-modulation** apparently due to the non-linearity of the **ionosphere,** which causes a receiver tuned to the frequency of a powerful transmitter to also receive the transmission of some other powerful transmitter on a different frequency.

LUXMETER, LUXOMETER. A device which measures **illumination** in **lux** units.

LYMAN GHOSTS. Discussed under **ghosts.**

LYMAN SERIES. A series of lines in the **ultraviolet** region of the spectrum of atomic hydrogen. The wave numbers of the lines in this series are given by the relationship:

$$\bar{\nu} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

where $\bar{\nu}$ is the wave number of a line in the Lyman series, R_H is the **Rydberg constant for** hydrogen (109, 677.591 cm^{-1}), n_1 is 1, and n_2 has integral values greater than 1.

LYOPHILIC SOL. A **colloidal system** in which there is mutual affinity of the dispersed phase and dispersion medium. This term applies to reversible or stable colloids. Examples are gelatine or albumin sols in water.

LYOPHILIC SYSTEM. A **colloidal system** in which there is a marked attraction between the disperse phase and the dispersion medium. When the medium is water, the term hydrophile is applied to the system.

LYOPHOBIC SOL. A **colloidal system** in which there is little mutual affinity between the **dispersed phase** and the **dispersion medium.** The term applies to the irreversible or unstable type of colloid. An example is gold sol in water.

LYOPHOBIC SYSTEM. A **colloidal system** of the unstable or irreversible type (suspensoids). (See **lyophobic sol.**)

LYOTROPIC SERIES. A series of **anions or cations** arranged in the order of magnitude of their effect upon reactions in **colloidal solutions.** In the precipitation of lyophilic colloids such as gelatine by salts the anions or the cations may be arranged in the order of their coagulating power. This is called the Hofmeister or lyotropic series.

Anions:

$$SO_4^{=} > Cl^- > Br^- > I^- > CNS^-.$$

Cations:

$$Ba^{++} > Li^+ > Na^+ > K^+ > Rb^+ > Cs^+.$$

This order runs parallel to the solubility of the salts in water and to their tendency to become hydrated. It has been suggested that the precipitation is due to the dehydration of the colloid as well as to a reduction in the **zeta potential.**

M

M. (1) Meter (m). (2) Mass (m or M). (3) Mass of molecules or atom (m or m_m). (4) Mass of electron (m_e). (5) Mass (rest) (m_0). (6) Modulation factor (m). (7) Molecular weight (M) (8) Direction cosine (l, m, n). (9) Mesh (m or M). (10) Slope of equilibrium curve (m). (11) Metal (M). (12) One-thousandth (m). (13) Strength of magnetic pole (m, but p is preferred). (14) Magnetization or intensity of magnetization (**M**). (15) Magnetic moment (**m**). (16) Total magnetic quantum number (M). (17) Linear magnefication (m). (18) Order of spectrum (m). (19) Number of electric phases (m). (20) Magnetic quantum number of electron (m). (21) Magnetic quantum number of electrons (M) (22) Paschen-Back effect quantum numbers associated with N and S (M_N, M_S).

M-CENTER. See **color center.**

M-ELECTRON. An electron characterized by having a **principal quantum number** of value 3 (See also **M-shell.**)

M-LINE. One of the lines in the M-series of **x-rays** that are characteristic of the various elements and are produced by **excitation** of the electrons of the **M-shell.**

M/N RATIO. (1) In radiation chemistry, the **ion yield.** (2) In nuclear physics a ratio of conversion fractions for the M and N shells analogous to the **K/L ratio.**

M-RADIATION. One of a series of **x-rays** characteristic of each element that is excited when that element, commonly as the metal, is used as an **anticathode** in an x-ray tube, so as to excite the electrons of the **M-shell.**

M-SHELL. The collection of all those electrons in an atom that are characterized by the **principal quantum number** three. The M-shell consists of one electron in the case of sodium (atomic number = 11) and increases by one electron for each element of successively higher atomic number until argon (atomic number = 18), which has 8 electrons in its M-shell, is reached. The M-shells of potassium (atomic number = 19), calcium (atomic number = 20), scandium (atomic number = 21), and titanium (atomic number = 22) all contain 8 electrons, the additional electrons of these elements appearing in the beginning N-shell. With vanadium (atomic number = 23), however, there are 10 electrons in the M-shell; in chromium (atomic number = 24), there are 11 electrons in the M-shell; and in manganese (atomic number = 25), there are 13 electrons in the M-shell, and then the elements of successively higher atomic number increase the number of electrons in the M-shell by one each until zinc (atomic number = 30) is reached All elements of higher atomic number contain 18 electrons in the M-shell

MACBETH ILLUMINOMETER. A device for optically matching the **brightness** of a surface with a known, variable, surface-brightness.

MACH ANGLE. The apex angle of a **Mach cone.**

MACH CONE. The wavefront of a **Mach wave.**

MACH CRITERION. Only those propositions should be employed in physical theory from which statements about observable phenomena can be deduced.

MACH NUMBER. The ratio of the speed of an object to the speed of sound in the undisturbed medium in which the object is traveling.

MACH PRINCIPLE. The inertia of any system arises from the interaction of that system and the rest of the universe, including distant parts thereof. Postulated by applying the **Mach criterion** to the concept of absolute space. Applied by Einstein to the hypothesis that the **metric** of space-time is determined by the distribution of matter and energy.

MACH WAVE. The shock wave set up by an object traveling with a **Mach number** greater than unity.

MACHE UNIT. A unit of quantity of **radioactive emanation,** defined as the quantity of emanation which sets up a saturation current equal to one one-thousandth of the electrostatic unit of current. It is equal to 3.6×10^{-10} **curie.**

MACHINES. The term machine applies traditionally in physics to any one of those simple devices—lever, inclined plane, etc.—which might with greater propriety be called "elements of mechanism." These elementary machines fall into two general classes, those dependent upon the vector resolution of forces (inclined plane, wedge, screw, toggle joint), and those in which there is an equilibrium of torques (lever, pulley, wheel-and-axle). Their detailed explanation is to be found in any textbook of high school physics. For each of the several types, there is a factor known as the "mechanical advantage," which ideally represents the ratio of the force exerted by the device to the force acting upon it; though on account of friction and elasticity, the actual ratio of the force may differ somewhat from this ideal value. For a lever, it is equal to the ratio of the "arms"; for an inclined plane, with the force acting parallel to the plane, it is the cosecant of the angle of inclination; etc. Ordinarily a more practicable measure of the mechanical advantage is the ratio of a small displacement produced by the operator of the machine to the resulting displacement of the load by the machine Thus, if the handle of an automobile jack is moved 1″, in lifting the car 0.002″, the mechanical advantage is 500.

The principles of **efficiency** (ratio of output energy to input energy) are well illustrated by the action of machines. No mechanism can operate without loss of energy through friction or otherwise; hence the efficiency of a machine is always less than unity. Otherwise, it would be possible to realize **perpetual motion.**

MACKENZIE EQUATION (FECHNER LAW).

$$S = c \log_{10} p + a,$$

where S = sensation of loudness, p = excess pressure, a, c = frequency-dependent parameters. This equation has been applied to sensations other than that of loudness. It is not a satisfactory expression unless the parameter a is considered to depend on the past history of the subject.

MACKEREL SKY. Both **altocumulus and cirrocumulus** clouds often appear arranged in uniform bands similar in appearance to a mackerel's back. The reference pertains particularly to altocumulus.

MACLAURIN SERIES. See **Maclaurin theorem.**

MACLAURIN THEOREM. A special case of the **Taylor theorem.** If $f(x)$ and all of its derivatives remain finite at $x = 0$, then $f(x)$ may be expanded to

$$f(x) = f(0) + f'(0)x + f''(0)\frac{x^2}{2!} + \cdots + f^{(n-1)}(0)\frac{x^{n-1}}{(n-1)!} + R_n$$

where R_n is the **remainder** after n terms. When the remainder converges towards zero as the number of terms increases, the result is the **Maclaurin series** for $f(x)$ at $x = 0$.

MACLEOD EQUATION. A constant relationship between the **surface tension** of a liquid, its density, and the density of its vapor, of the form:

$$\frac{\gamma^{1/4}}{\rho - \rho'} = \text{Constant}$$

where γ is the surface tension of the liquid, ρ is its density, and ρ' is the density of its vapor.

MACROMOLECULE. A term sometimes applied to a crystalline solid, such as diamond, where the atoms are covalently bonded (see **covalence**) to their neighbors in such a way that the bonds are all of equal strength so that the whole crystal is, as it were, one single chemically-bonded molecule.

MADELUNG CONSTANT. A constant appearing in the term for the **Coulomb energy** ϕ of an ionic crystal (see **Born-Mayer equation**). It may be defined by α in the equation

$$\phi = -\frac{\alpha e^2}{R}$$

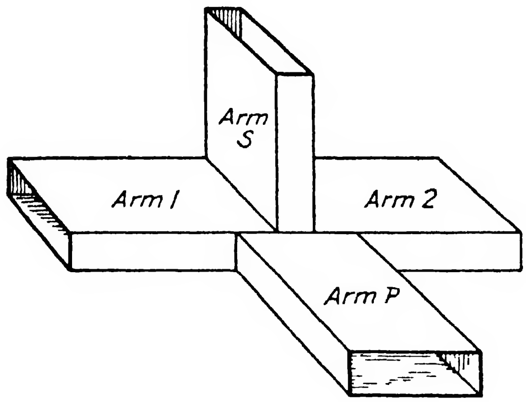
where R is the separation of nearest neighbors in the crystal, and is evaluated by adding the mutual electrostatic potential energies of all the ions in the particular lattice. The Madelung constant also appears in the expression for the wavelength of the **residual radiation** (Reststrahlen) selectively reflected by a given heteropolar crystal.

MAGAMP. Abbreviation for **magnetic amplifier.**

MAGIC EYE TUBE. One form of an indicator tube. (See **tuning indicator; tube, magic eye.**)

MAGIC NUMBERS. Certain numbers of **neutrons** or **protons** in the nucleus which give rise to increased nuclear stability. The levels that seem certain at this time correspond to values of N (number of neutrons in the nucleus) or of Z (atomic number: number of protons in the nucleus) equal to 2, 8, 20, 28, 50, 82, and 126. For example, tin ($Z = 50$) has as many as ten stable isotopes

MAGIC TEE. A **hybrid waveguide junction** which is a combination of an E-plane tee and an H-plane tee (see figure). Since the wave-



One form of a microwave magic tee (By permission from "Microwave Theory and Techniques" by Reich et al., Copyright 1953, D. Van Nostrand Co., Inc)

guide dimensions are such that only $TE_{1,0}$ propagation is possible, and the E-field in the parallel arm P is normal to that in the series arm S, there is no direct transmission between the series and parallel arms if they are symmetrically placed. The characteristics of series and shunt tees are such that when waves of equal amplitude and phase enter the P and S arms, the outputs cancel in one of the side-arms and add in the other. By the **reciprocity principle,** therefore, energy applied to 1 or 2 is divided equally between the P and S arms, none emerging from the opposite side-arms.

MAGNAL BASE. A **cathode-ray tube** base having eleven pins.

MAGNALIUM. An alloy of aluminum and magnesium which has high **reflectivity** in the visible and ultraviolet regions.

MAGNESIUM. Metallic element. Symbol Mg. Atomic number 12.

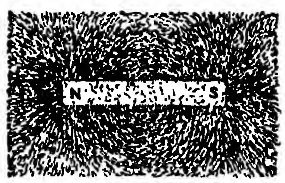
MAGNESIUM-COPPER SULFITE RECTIFIER. A dry disk **semiconductor rectifier** having a **barrier layer** consisting of copper sulfite in contact with a magnesium plate.

MAGNESTAT. Trade name for a **magnetic amplifier.**

MAGNESYN. Trade name for a **selsyn.**

MAGNET. In ancient times it was known that stones containing magnetite (see **iron**) had qualities which were not the property of other stones. It was found that they would attract iron, and when freely supported would turn so that their axis would take a north-south direction. These lodestones were the earliest magnets, but now are natural curiosities only, since the magnets used in compasses, instruments, magnetos, and all the various array of equipment which embodies a magnetic field produced by a magnet, are artificially constructed of hardened steel, magnetized by a strong magnetic flux. This type of magnet may be said to be a permanent magnet, in contrast to the **electromagnet.**

A magnet is a body possessing the property of attracting magnetic substances. The so-called permanent magnet should be used



Graphical magnetic field of a bar magnet

where a constant magnetic field is to be produced, since a well-made permanent magnet loses its magnetism very slowly, and then only up to a certain point, after which it is said

to be aged. Thereafter it maintains a constant degree of magnetism unless subjected to strong de-magnetizing effects. Manufacturers of permanent magnets for precision instruments artificially age them during the process of manufacture. A bar which has been magnetized is found to have poles. These are centers where magnetic attraction is strongest. If the magnet is free to turn, the pole which points northerly is called a north pole, and the other a south pole. Like poles repel each other with a magnetic force, and unlike poles attract each other. The earth is a large magnet having magnetic poles somewhere near, but not coincident with, the geographic poles. Since unlike poles attract each other, and the north pole of a magnet is taken as that which points northerly, it is the earth's south magnetic pole which lies near the north geographic pole. A magnet, delicately made, and freely suspended, becomes a **compass.**

MAGNETIC. In addition to its general dictionary meaning of "pertaining to magnetism," magnetic carries a technical implication of **ferromagnetic.**

MAGNETIC AMPLIFIER. See **amplifier, magnetic.**

MAGNETIC AMPLIFIER AMPLIFICATION. See **amplification, ampere-turn; amplification, current; amplification, power** (2); **amplification, voltage.**

MAGNETIC AMPLIFIER, BRIDGE. A **magnetic amplifier** in which each of the gate windings is connected in series with an appropriate arm of a bridge rectifier (see **rectifier, bridge**). The rectifiers provide the effect of self-saturation and d-c output.

MAGNETIC AMPLIFIER, FIGURE OF MERIT. The ratio of the **power gain** divided by the **time constant** under specified operating conditions. The time constant may be expressed either in seconds or cycles (number of cycles for 63% change, or T/f, where T is the time constant (seconds) and f is the supply frequency (cycles per second)). Sometimes referred to as dynamic power gain.

MAGNETIC ANALYSIS. See **mass spectrograph.**

MAGNETIC ANISOTROPY. The dependence of magnetic properties on direction; e.g., a crystal exhibits "hard" and "easy" directions for **magnetization.** As one result, a magnetizing force **H** not parallel to a crystal axis, will produce induction **B** that is not parallel to **H**. The "ratio" of **B** to **H** is no longer a number (μ), but becomes a **tensor.**

MAGNETIC ARMATURE LOUDSPEAKER. See **loudspeaker, magnetic.**

MAGNETIC ATTRACTION. See **attraction, magnetic.**

MAGNETIC BIASING. The simultaneous conditioning of the magnetic recording medium during recording by superposing an additional magnetic field upon the signal magnetic field. In general, magnetic biasing is used to obtain a substantially linear relationship between the amplitude of the signal and the permanent flux density in the recording medium.

MAGNETIC BIASING, A-C. In magnetic recording, **magnetic biasing** accomplished by the use of an alternating current, usually well above the signal-frequency range.

MAGNETIC BIASING, D-C. In magnetic recording, **magnetic biasing** accomplished by the use of direct current.

MAGNETIC CIRCUIT. A magnet, or a coil of wire carrying a current, is the seat of an influence which extends outward from it and is called a **magnetic field.** The flux from a bar magnet or from a straight electromagnet issues from one end of the magnet or coil, bends around, and re-enters at the other end. This can be exhibited by exploring the region with a compass needle. If there is provided an iron frame or ring extending from one pole of the magnet or coil around to the other, and in case of the coil, running clear through it, the magnetic flux is not only concentrated largely in the iron but is much greater in total amount than if the induction is entirely in the air. Even a short air gap in the iron reduces the flux considerably.

The analogy of such a magnetic path to an electric circuit is easily seen. The magnetic flux corresponds to a current. The magnet or coil corresponds to a battery, and provides magnetomotive force just as a battery supplies electromotive force. The amount of flux produced by a given magnetomotive force depends upon the dimensions and material of

the "magnetic circuit," e.g., the length and cross-section of the iron ring followed by the flux and the permeability of the iron; just as the dimensions and material of the electric conductor determine its resistance. This attribute of the magnetic circuit (corresponding to resistance) is called its reluctance.

It must be remembered that this analog is purely mathematical, not physical. In magnetism, there is no flow of charge, as in electricity. Hence "flux" tends to be misleading.

These ideas are expressed quantitatively for the purpose of practical calculations. The magnetomotive force $\mathfrak{F}$ is commonly given in "ampere-turns." Thus, a coil of 50 turns carrying a current of 4 amperes has a magnetomotive force of 200 ampere-turns. Another unit of magnetomotive force sometimes used is the "gilbert," equal to $5/2\pi$ or 0.794 ampere-turn. The flux ϕ is expressed in webers (mks) or maxwells (emu). Just as the resistance of an electric circuit is defined as the ratio of the electromotive force to the current, so the measure of the reluctance $\mathcal{R}$ of a magnetic circuit is the ratio of the magnetomotive force to the flux. We then have the relation

$$\phi = \frac{\mathfrak{F}}{\mathcal{R}},$$

a sort of magnetic Ohm's law, known as Bosanquet's law.

There are approximate formulae, used in electrical engineering, for calculating $\mathfrak{F}$ and $\mathcal{R}$, and hence ϕ, from the specifications of a coil, its core, air gaps, etc. Such formulae are extensively used in designing transformers, generators, motors, etc. (See **electromagnet.**)

MAGNETIC CONSTANT (SYMBOL μ_v OR γ_m) (SOMETIMES μ_0). The magnetic constant pertinent to any system of units is the scalar dimensional factor relating the mechanical force between two currents to their magnitudes and geometrical configurations. It is related to the **electric constant** by $\gamma_e\gamma_m = 1/c^2$. In the usual three-dimensional **emu system,** γ_m is assigned the value unity, a pure numeric. In the **esu system,** $\gamma_m = 1/c^2 = 1.1 \times 10^{-21}$ sec²/cm². In the unrationalized mksa (Georgi) system, $\gamma_m = 10^{-7}$ henry/meter, and 4π times this value in the rationalized mksa system. The symbols μ_0 and ϵ_0 are often used for the fundamental magnetic and electric constants, but unfortunately μ_0 is also the accepted symbol for initial permeability (see **permeability, initial**) of magnetic materials.

MAGNETIC CONSTANT - CURRENT STANDARD (REFERENCE). A **saturable reactor** arranged with a constant magnetic **bias** provided by permanent magnets. With the aid of compensating windings, the average value of the rectified output current can be made to be extremely constant over a considerable range of supply voltage and frequency.

MAGNETIC CORE TAPE. See **tape, magnetic core.**

MAGNETIC COUPLING. See **inductive coupling.**

MAGNETIC CURRENT. Since the total electric current density (**conduction** plus **displacement**) is given by $\nabla \times \mathbf{H}$ (**Maxwell equations**), it is convenient to call

$$\partial \mathbf{B}/\partial t = -\nabla \times \mathbf{E}$$

a "magnetic current density."

MAGNETIC DAMPING. See the **Lenz law.**

MAGNETIC DEFLECTION OF ELECTRON BEAM. See **cathode-ray tube.**

MAGNETIC DIPOLE. A convenient fiction for describing the first order properties of **magnetic moment.** The dipole is conceived as two closely-spaced magnetic poles of opposite sign, but equal strength. (See **magnetic pole-strength.**)

MAGNETIC DIPOLE RADIATION. See **dipole radiation, magnetic.**

MAGNETIC DOUBLE LAYER. See **magnetic shell.**

MAGNETIC ENERGY. In the **Poynting theorem,** the volume integral of

$$\mathbf{H} \cdot \frac{\partial \mathbf{B}}{\partial t}$$

is interpreted as the rate of change of magnetic energy. Since

$$\mathbf{B} = \mu\mathbf{H}; \quad \mathbf{H} \cdot \frac{\partial \mathbf{B}}{\partial t} = \frac{\partial}{\partial t}\left(\frac{\mu \mathbf{H}^2}{2}\right)$$

so

$$\frac{\mu \mathbf{H}^2}{2} = \frac{\mathbf{B} \cdot \mathbf{H}}{2}$$

is interpreted as the energy per unit volume stored in a magnetic field. This is the basic reason that the product **BH** is of practical importance in permanent-magnet materials.

MAGNETIC ENERGY PRODUCT. The product **BH** for a given point on the demagnetization curve. (See **magnetic energy, hysteresis loss.**)

MAGNETIC FIELD. A vector-function field described by the **magnetic induction (B)**. The term magnetic field is used interchangeably to refer to induction (**B**) and magnetizing force (**H**). (See also **magnetostatics, laws of magnetism, fields of force.**)

MAGNETIC FIELD ENERGY. See **magnetic energy; energy of a system of currents.**

MAGNETIC FIELD OF A CURRENT. The magnetic field of a current may be described by the **magnetizing force** produced, via the magnetic moment of the current. The **magnetic moment** of any current loop is

$$\mathbf{m} = I\int \mathbf{n}da$$

which is independent of the surface spanning the contour, hence depends only on the current and the loop contour. With respect to an arbitrary origin of coordinates, this can be written

$$\mathbf{m} = \frac{I}{2}\int \mathbf{r} \times d\mathbf{r}$$

where **r** is the radius vector to a point on the current loop. In terms of current density this becomes

$$\mathbf{m} = \tfrac{1}{2}\int \mathbf{r} \times \mathbf{J}dV.$$

(See **magnetic potential; vector potential.**)

MAGNETIC FIELD STRENGTH (*H*). See **magnetizing force.**

MAGNETIC FLIP-FLOP. A bistable circuit employing one or more **magnetic amplifiers** so arranged as to have two discrete levels of output which may be obtained by adjusting the control voltage or current

MAGNETIC FLUX. The magnetic flux through any closed figure, such as a circle, a rectangle, or a loop of wire, is the product of the area of the figure by the average component of **magnetic induction** normal to that area. Specifically,

$$\phi = \int \mathbf{B} \cdot d\mathbf{s}.$$

Thus, if a rectangle 5 cm $\times$ 8 cm is placed in a region where there is a uniform magnetic induction of 2500 gauss, and at an angle of 30° with the lines of induction, the magnetic flux through it is 2500 gauss $\times$ 40 cm^2 $\times$ sin 30° = 50,000 gauss-cm^2 or **"maxwells."** The magnitude of this quantity is often conventionally represented by imagining the lines of induction to be so spaced that the number of them through a given area is equal to the number of gauss-cm^2 or maxwells of flux through that area. The flux in the above example would be commonly expressed as 50,000 "lines" When a coil has several (n) turns and each turn has approximately the same flux (ϕ) through it, the effect is the same as for a single loop with the flux $n\phi$ through it. This product, which is called "linkage," is expressed in "maxwell-turns" or "line-turns" The magnetic flux or the linkage through a loop or a coil may be measured by putting into the circuit a ballistic (undamped) galvanometer and then suddenly removing the flux (or the coil). If the resistance of the whole circuit and the constant of the galvanometer are known, the flux may be calculated from the "throw" of the galvanometer In the **mksa system**, the unit of flux is the **weber.** (One weber = 10^8 maxwell) (See also **magnetic induction.**)

MAGNETIC FOCUSING. See **focusing, magnetic.**

MAGNETIC GATE. A **magnetic amplifier** used as a **gate.**

MAGNETIC HEAD. In magnetic recording, a **transducer** for converting electric variations into magnetic variations for storage on magnetic media, for reconverting energy so stored into electric energy, or for erasing such stored energy.

MAGNETIC HEAD, DOUBLE POLE-PIECE. A **magnetic head** having two separate pole-pieces in which pole faces of opposite polarity are on opposite sides of the medium. One or both of these pole-pieces may be provided with an energizing winding.

MAGNETIC INDUCTION (B) (MAGNETIC FLUX DENSITY). Magnetic induction is the basic observable property of a **magnetic field.** It is directly associated with the force on a current element or the electromotive force induced in a moving conductor. The mechanical force on a length dl of a circuit carrying a current I is given by

$$d\mathbf{F} = I d\mathbf{l} \times \mathbf{B}.$$

The electromotive force induced in a conductor of length $d\mathbf{l}$ moving with a velocity $\mathbf{v}$ is given by

$$dE = \mathbf{B} \times \mathbf{v} \cdot d\mathbf{l}.$$

MAGNETIC INTENSITY OR MAGNETIC FIELD STRENGTH. See **magnetic field; magnetizing force; oersted;** and **ampere-turn per meter.**

MAGNETIC LAG. When the **magnetizing force** is changed, the **induction** does not take on its final (equilibrium) value instantaneously. There are three principal kinds of lag: (1) **Eddy current** lag; (2) Temperature sensitive lag due to impurities; (3) Jordan lag (constant phase-angle). The last of these is not sensitive to temperature or frequency.

MAGNETIC LENS. An arrangement of coils, electromagnets, or magnets so disposed that the resulting magnetic fields produce a focusing force on a beam of charged particles. (See also **electron lens.**)

MAGNETIC LINE OF FORCE. See **fields of force; field, magnetic.**

MAGNETIC LOUDSPEAKER. See **loudspeaker, magnetic armature.**

MAGNETIC MEMORY. A bistable magnetic device employed to store information. The simplest and probably most common example is simply a **core** made from a magnetic material such as Deltamax which possesses a nearly rectangular **hysteresis loop** ($B_r/B_s \to 1$). It is thus capable of "remembering" indefinitely whether or not it has been magnetized.

MAGNETIC MICROPHONE. See **microphone, variable-reluctance.**

MAGNETIC MODULATOR. A modulator employing a **magnetic circuit** as the modulating element.

MAGNETIC MOMENT. The magnetic moment of a current loop or a magnetized body is a measure of the magnetizing force (**H**) produced by the current or magnetized body. The magnetic moment of a plane current loop is a vector (**m**), normal to the plane of the loop and directed so that the current has a clockwise rotation around **m.** The magnitude of **m** is the product of the current and loop area. The magnetic moment of a magnetized body is the vector summation of the magnetic moments of the internal current loops and spins of the body. The magnetizing force produced at a displacement **r** from a small source of moment **m**

$$\mathbf{H} = -\nabla \frac{\mathbf{m} \cdot \mathbf{r}}{r^3}.$$

(See also **dipole moment.**)

MAGNETIC MOMENT (ELECTRON), ANOMALOUS. See **anomalous magnetic moment (electron).**

MAGNETIC MOMENT DENSITY (M). The volume density of **magnetic moment;** the ratio of magnetic moment to volume (of a magnetized body), for vanishingly small volume.

$\mathbf{B} = \gamma_m(\mathbf{H} + 4\pi\mathbf{M})$ (in unrationalized units)

where γ_m is the **magnetic constant.** In rationalized units, the factor 4π is deleted. (See **induction, intrinsic.**)

MAGNETIC MOMENT, NUCLEAR OR ATOMIC. The magnetic moment of a nuclear or atomic particle or system of particles usually denotes the magnetic dipole moment. For a particle or system in a magnetic field, the interaction energy is the negative of the product of the **field strength** by the component of the magnetic **dipole moment** of the particle in the direction of the field ($-\mu_H H$). A magnetic moment is associated with the intrinsic spin of a particle and with the orbital motion of a particle in a system, e.g., nuclei with finite spins have finite magnetic moments between about -2 and $+6$ nuclear Bohr magnetons.

MAGNETIC MOMENT OF MOLECULAR BEAM. See **Stern-Gerlach experiment.**

MAGNETIC PENDULUM. A bar magnet poised on a pivot or suspended by a thread in a magnetic field having a horizontal compo-

nent will, if disturbed and released, oscillate in a horizontal plane as a magnetic pendulum. This arrangement is commonly employed in the **magnetometer** method of measuring the earth's magnetic field intensity, or in comparing field intensities in different localities.

MAGNETIC POLARIZATION. See **induction, intrinsic.**

MAGNETIC POLARIZATION, OPTICAL. The **optical activity** shown in a magnetic field by an optically inactive substance. (See also **Cotton-Mouton effect.**)

MAGNETIC POLE (*p*). A convenient fiction for describing certain magnetostatic phenomena. A simple magnet has a field that appears to emanate from one "pole" and return to another. Poles have no physical reality, but are convenient descriptive devices. (See **magnetic pole-strength.**)

MAGNETIC POLE-STRENGTH. When using the convenient fiction of **magnetic poles** quantitatively, "strength" must be assigned to allow computation. A magnet having a moment **m** is considered to have two poles, $+p$ and $-p$, separated by a distance **l**, such that **m** = p**l**. The **torque** on such a magnet in a field **B** is

$$\mathbf{T} = \mathbf{m} \times \mathbf{B}$$

and can be interpreted as due to forces $+p\mathbf{B}$ and $-p\mathbf{B}$ exerted on the poles. The **magnetizing force** due to the moment can likewise be interpreted as the superposition of radial magnetizing forces due to the separate poles. of

$$\mathbf{H}_1 = p/r^2, \mathbf{H}_2 = -p/r^2.$$

The interaction between two magnets can therefore be interpreted as the combination of forces between the poles, where the force between any two poles is given by the **Coulomb law:**

$$F = \frac{\mu p_1 p_2}{r^2} \quad (\text{since } \mathbf{B} = \mu\mathbf{H}).$$

MAGNETIC POTENTIAL. Since the **curl of a magnetostatic field** in a current-free region vanishes, i.e.,

$$\nabla \times \mathbf{B} = 0, \nabla \times \mathbf{H} = 0,$$

the vectors **H** and **B** are derivable from scalar potentials,

$$\mathbf{H} = -\nabla U$$

(see **wave potentials**). The potential U at the position **r**, due to an element of magnetic moment **m** at the origin, is

$$U = -\mathbf{m} \cdot \nabla \left(\frac{1}{r}\right) = \frac{\mathbf{m} \cdot \mathbf{r}}{r^3}.$$

(See **magnetic field; magnetic moment; vector potential; magnetic field of a current.**)

MAGNETIC POTENTIOMETER. See **potentiometer, magnetic.**

MAGNETIC PRINTING (MAGNETIC TRANSFER) (CROSSTALK). The permanent transfer of a recorded signal from a section of a magnetic recording medium to another section of the same or a different medium when these sections are brought in proximity.

MAGNETIC RECORDER. Equipment incorporating an electromagnetic **transducer** and means for moving a ferromagnetic recording medium relative to the transducer for recording electric signals as magnetic variations in the medium. However, the generic term 'magnetic recorder" can also be applied to an instrument which has not only facilities for recording electric signals as magnetic variations, but also for converting such magnetic variations back into electric variations.

MAGNETIC RECORDING. See **tape recording; wire recording; sound recording.**

MAGNETIC RECORDING HEAD. A **magnetic head** for transforming electric variations into magnetic variations for storage on magnetic media.

MAGNETIC REPRODUCING HEAD. A **magnetic head** for converting magnetic variations on magnetic media into electric variations.

MAGNETIC RESONANCE SPECTRUM. See **spectrum, magnetic resonance.**

MAGNETIC RIGIDITY ($H\rho$). A measure of the momentum of a particle equal to the product of the **magnetic intensity** perpendicular to the path of the particle, and the resultant radius of curvature of the path of the particle.

MAGNETIC ROTATION. See **Faraday effect.**

MAGNETIC SCALAR POTENTIAL. See **wave potentials.**

MAGNETIC SHELL. A hypothetical double-layer of magnetic charge, analogous to an **electric double layer.** Alternatively, it can be conceived as a layer of magnetic **dipoles,** all oriented in the same sense (but not direction).

MAGNETIC SHELL, EQUIVALENT. The **magnetic field of a current** is equivalent to the field of a hypothetical double-layer of magnetic charge, of magnetic moment per unit area given by In. For the summation of magnetic moment over the shell is

$$\int In\,da,$$

which is identically the moment of the **current loop.**

MAGNETIC SHIELDING. Since magnetic materials of high **permeability** act like good "conductors," i.e., offer small **reluctance,** a box of high μ material shields its interior from an external magnetizing force.

MAGNETIC SPEAKER. See **loudspeaker, magnetic.**

MAGNETIC STORM. Erratic changes in the earth's magnetic field, believed due to sun-spot activity. Sometimes magnetic storms seriously limit both radio and wire communications.

MAGNETIC STRAIN ENERGY (E_σ). A component of **potential energy in a magnetic domain,** given by:

$$E_\sigma = \tfrac{3}{2}\lambda_s\sigma \sin^2\theta$$

where λ_s is the **magnetostriction** expansion occurring between the demagnetized state and saturation, σ the tensile stress to which the domain is subject, and θ the angle between the magnetization and the tension.

MAGNETIC SUSCEPTIBILITY (κ, χ). The magnetic susceptibility per unit volume of an isotropic material is the **polarization** divided by the **induction** that would exist at the point in **free space;** i.e.,

$$\kappa = \frac{P_i}{\gamma_m H} = \frac{B_i}{4\pi\gamma_m H}$$

$$= \frac{M}{4\pi H} \quad \text{unrationalized units}$$

$$= \frac{B_i}{\gamma_m H} = \frac{M}{H} \quad \text{rationalized units.}$$

The mass susceptibility is the volume **susceptibility** divided by the mass density:

$$\chi = \kappa/\rho.$$

Volume susceptibility κ is related to specific permeability μ_s (see **permeability, specific**) by

$$\mu_s = 1 + 4\pi\kappa$$

and again the factor 4π is dropped in rationalized units. Note that the magnitude of susceptibility differs by a factor of 4π in rationalized and unrationalized units, but that μ_s is unaffected by rationalization. (See **induction, intrinsic; magnetic moment density.**)

MAGNETIC TAPE. A magnetic-recording medium having a width greater than approximately 10 times the thickness. This tape may be homogeneous or coated.

MAGNETIC THERMOMETER. In the temperature region accessible by adiabatic demagnetization of a paramagnetic salt (below 1°K), the **susceptibility** of the salt can be used as a thermometric process. The "magnetic temperature," usually denoted by T*, can be directly related to the absolute temperature by the **Curie law** (susceptibility × absolute temperature = constant) in the temperature range where the salt used obeys this law. At lower temperatures T* can be related to the true absolute temperature by carrying out a thermodynamic cycle in which the susceptibility and heat capacity are determined.

MAGNETIC TRANSFER. See **magnetic printing.**

MAGNETIC VECTOR. See **radiation field.**

MAGNETIC VECTOR POTENTIAL. See **wave potentials.**

MAGNETIC WAVES. The spreading of **magnetization** from a small region of a specimen, where a sudden change of field has been made.

MAGNETISM. The science treating of the laws and conditions of **magnetic force** and its effects, or that agency or quality to which magnetic force is due. (See also **magnet; electromagnet.**)

MAGNETISM AND MOLECULAR STRUCTURE. The magnetic properties of molecules, apart from the **diamagnetism** associated with their electron clouds, depend on whether there are any unpaired electron spins or orbital motions having magnetic moments. Measurements of the susceptibility will detect any **paramagnetism** due to these, and may be compared with the predictions from various alternative molecular structures. More refined techniques, such as **paramagnetic** and **nuclear resonance**, may give detailed information concerning the actual **wave functions** of the electrons.

MAGNETISM BY INDUCTION. The production of magnetization in a ferromagnetic material as a result of the material being placed in a **magnetic field.**

MAGNETISM, LAWS OF. The laws of magnetism are those of electromagnetism under steady-state conditions. The pertinent **Maxwell equations** reduce to

$$\nabla \times \mathbf{H} = \mathbf{J}$$

$$\nabla \cdot \mathbf{B} = 0.$$

In addition, the equation of continuity becomes

$$\nabla \cdot \mathbf{J} = 0$$

since there is no **displacement current.** By the **Stokes theorem,** the first equation can be expressed in integral form as

$$\oint \mathbf{H} \cdot d\mathbf{l} = I$$

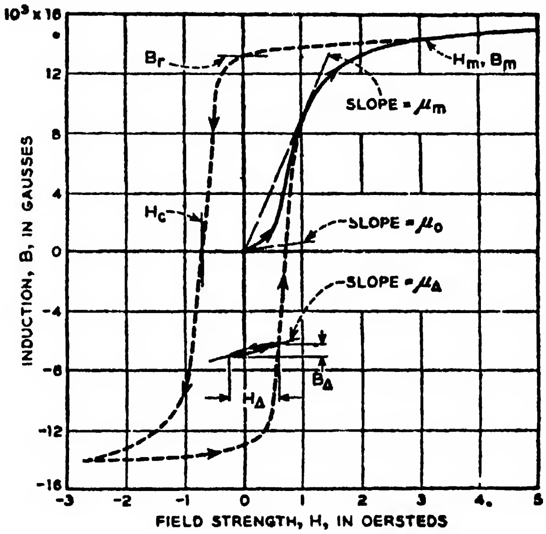
(the current linked).

MAGNETISM, MOLECULAR THEORY OF. See **Ewing theory; Weiss theory.**

MAGNETIZATION AND EXTERNAL FIELD, MUTUAL ENERGY BETWEEN. See **mutual energy between magnetization and external field.**

MAGNETIZATION, CONSTRAINED. See **impeded harmonic operation.**

MAGNETIZATION CURVE. An originally unmagnetized specimen of magnetic material, when subjected to an increasing magnetizing force (H) develops the induction (B) shown in the solid curve. This solid curve is called the magnetization curve, and is not retraced as H is reduced. The initial slope of the magnetization curve is the initial permeability (μ_0). If H is carried to some maximum value H_m and then reduced (to $-H_m$), B follows the dotted hysteresis curve. The residual induction B_r is the induction remaining when H has been reduced to zero; the reverse H needed to reduce B to zero is called the coercive force (H_c). If H (and therefore also B) goes through a small cyclic change starting from an arbitary point on the hysteresis loop (see figure), a minor loop is described, with an



Magnetization curve (solid) and hysteresis loop (dotted) Some important magnetic quantities are illustrated (By permission from "Ferromagnetism" by Bozorth, Copyright 1951, D Van Nostrand Co, Inc)

average slope μ_Δ, called incremental permeability. If the cyclic change of H approaches zero, μ_Δ approaches a limit μ_r, the reversible permeability. If the positive and negative peaks of H are equal in a cyclic magnetization, the hysteresis loop is symmetrical. As the peak value H_m is increased (making larger loops), the loop tips trace a path called the normal magnetization curve. (See also **hysteresis.**)

MAGNETIZATION, FORCED. See **impeded harmonic operation.**

MAGNETIZATION, FREE. See **unimpeded harmonic operation.**

MAGNETIZATION, IDEAL. The **magnetization** remaining at a constant magnetizing force H after a superposed alternating ΔH has been slowly reduced from a large value to zero.

MAGNETIZATION, INTENSITY OF (*I. J*). See **induction, intrinsic.**

MAGNETIZATION, NATURAL. See **unimpeded harmonic operation.**

MAGNETIZATION, SATURATION. The application of an increasing **magnetizing force** to a **ferromagnetic** substance yields a resulting intrinsic induction (P_m) that asymptotically approaches a constant value (P_s), the saturation magnetization.

MAGNETIZATION, SPONTANEOUS. The magnetic saturation of the **domains** of a **ferromagnetic** material, even in the absence of an applied **magnetizing force.** Each domain is magnetized to saturation at all temperatures below the **Curie point,** although the material as a whole may be unmagnetized because of the differing orientations of the various domains.

MAGNETIZING CURRENT. The component of current drawn by an **inductor, magnetic amplifier, transformer,** etc., which is required to establish the alternating component of flux.

MAGNETIZING FORCE (*H*). An auxiliary, vector point-function that measures the ability of electric currents or magnetized bodies to produce magnetic induction (B). It is measured in ampere-turns per meter (mks) or oersteds (emu). See **magnetic moment; magnetic field of a current.**)

MAGNETIZING FORCE, DYNAMIC. The applied **magnetomotive force** per unit length required to provide the flux and the rate-of-change of flux specified by the conditions for which a **dynamic hysteresis loop** is determined.

MAGNETOCALORIC EFFECT. The **reversible** heating and cooling of a specimen by changes of **magnetization.**

MAGNETOELASTIC COUPLING CONSTANTS. The coefficients of an expression containing products of elastic strains and magnetization directions, representing an interaction energy formally responsible for the phenomena of **magnetostriction.**

MAGNETOIONIC WAVE COMPONENT. Either of the two elliptically polarized wave components into which a linearly-polarized wave, incident on the **ionosphere,** is separated because of the earth's magnetic field.

MAGNETOMECHANICAL DAMPING. A component of energy loss associated with the elastic vibration of a magnetic material, produced by interaction of magnetic effects with stress and strain.

MAGNETOMECHANICAL FACTOR. The number g' occurring in the definition of the **magnetomechanical ratio.** The theory of the **gyromagnetic effect** predicts that g' should be nearly 2 for electron spins, and this is actually observed in ferromagnetic (see **ferromagnetism**) substances, showing that the orbital moments (for which g' is unity) are effectively quenched.

MAGNETOMECHANICAL RATIO. The ratio of the magnetic moment to the angular momentum, as observed in the **gyromagnetic effect.** This ratio is usually expressed in the form $g'e/2mc$ where g' is the **magnetomechanical factor.**

MAGNETOMETER. An apparatus used for measuring moderate magnetic field intensities, or sometimes the magnetic moments of magnets; frequently both. The standard laboratory equipment is set up in two ways, giving two results from which may be calculated both the magnetic field (or rather, its horizontal component B) and the magnetic moment m of a short bar magnet forming part of the equipment. The terrestrial magnetic intensity is often measured in this way, and Gauss employed this method in verifying the magnetic inverse-square law.

In the first arrangement, the magnet is used as a **magnetic pendulum,** whose **moment of inertia** I is known and whose period of oscillation T is measured. It is usually suspended by a fiber of known torsion coefficient K; in some cases K is small enough to be neglected. From the magnetic pendulum formula we obtain the product

$$mB = \frac{4\pi^2 I}{T^2} - K. \tag{1}$$

The magnet is then arranged to deflect a small compass needle. The needle is at O, the magnet at a considerable distance a from it, and commonly east or west of and aligned upon it. If the length of the magnet is l, the deflection δ of the needle is given by

$$\tan \delta = \frac{m}{B} \frac{32a}{(4a^2 - l^2)^2},$$

from which

$$\frac{m}{B} = \frac{(4a^2 - l^2)^2}{32a} \tan \delta. \qquad (2)$$

The second members of (1) and (2) contain only measurable quantities, and are therefore known. Hence, by multiplying (1) and (2) we get m^2, and by dividing (1) and (2) we get B^2; from those results m and B follow. Instruments embodying these principles are regularly used by the U.S Coast and Geodetic Survey.

Many modern measurements of magnetic field strength are made with saturable core instruments, or with search coils. Devices of this sort are also known as magnetometers.

MAGNETOMETER, FLUX-GATE. Some form of **saturable core device** in which the degree of saturation of the core by an external magnetic field is used as a measure of the strength of the field.

MAGNETOMETER, NULL ASTATIC. An instrument for measuring the **magnetization** of a specimen by balancing its **magnetic moment** against that produced by a small solenoid. With such a null instrument, films as thin as one-tenth micron, and weighing less than a milligram, have been investigated.

MAGNETOMOTIVE FORCE ($\mathfrak{F}$). Analog of electromotive force. The line integral of magnetizing force:

$$\mathfrak{F} = \int \mathbf{H} \cdot d\mathbf{l}.$$

The mmf around a closed contour is equal to $4\pi I$, where I is the *total* current linked by the contour. The relation

$$\oint \mathbf{H} \cdot d\mathbf{l} = 4\pi I$$

is also known as the Ampère law.

MAGNETON. See **Bohr magneton** and **Weiss magneton.**

MAGNETO-OPTICAL ANALYSIS. A method of chemical analysis based on differences in the lag of the **Faraday effect** behind the **magnetic intensity** for different substances.

MAGNETO-OPTICAL EFFECT (KERR MAGNETO-OPTICAL EFFECT). Kerr discovered that if plane-polarized light (see **light, plane-polarized**) is reflected normally from the polished pole of a strong electromagnet, the light becomes slightly elliptically-polarized The elipticity is so small that the effect may be considered merely as a rotation of the plane of vibration through an angle θ given by

$$\theta = KI$$

where I is the **intensity of magnetization** and K is the magnetic **Kerr constant.**

MAGNETO-OPTICAL ROTATION. See **Faraday effect,** and **magneto-optical effect.**

MAGNETOPHONE. Any recording device involving the magnetization of a ferromagnetic tape.

MAGNETORESISTANCE. Changes in electrical **resistivity** associated with changes of **magnetization.**

MAGNETOSTATIC FIELD. See **magnetostatics; magnetism.** A magnetic field may be described by the **magnetic induction B** and the **magnetizing force H** at all points. If these entities are independent of time, there is a magnetostatic field.

MAGNETOSTATICS. The study of **magnetic fields** that do not vary with time. Historically, it was believed to be a study of the behavior of magnetic poles (similar to electric charges) but such poles have never been found to exist. It is now believed that magnetostatics is the study of certain effects of steady motions of electric charge; charges at rest are described by **electrostatics,** charges in arbitary motion are the subject of **electromagnetism.** Electrostatics and magnetostatics are special phases of electromagnetism.

MAGNETOSTRICTION. The term literally implies magnetic contraction, but is generally understood to include a number of closely allied phenomena relating to ferromagnetic substances under magnetic influence.

(1) When an iron rod is subjected to a gradually increasing longitudinal magnetic field, it at first increases slightly in length (Joule effect) and later the length diminishes; when the magnetic intensity has reached about 250 oersteds, the rod has returned to its original length, and further increase of intensity causes it to contract (Villari reversal point). Nickel contracts rapidly at first and then remains nearly constant, while some iron-nickel alloys lengthen without reversal The following phenomena are also recognized (2) The Guillemin effect: the tendency of a bent ferromagnetic rod to straighten in a longitudinal field. (3) The Wiedemann effect: the twisting of a rod carrying an electric current when subjected to a magnetic field. (4) The Villari effect: a change of magnetic induction within an iron rod under longitudinal stress (inverse Joule effect).

Magnetostriction has been put to practical use in the magnetostrictive resonator, essentially an iron rod maintained in longitudinal elastic vibration by a high-frequency current in a helix wound upon it, and used, through the joint operation of the Joule and Villari effects, to control the frequency of the current, somewhat after the manner of the familiar **piezo-electric** (crystal) **resonator.**

MAGNETOSTRICTION, JOULE. A change in length parallel to an applied **magnetic field,** and produced by the field.

MAGNETOSTRICTION, LONGITUDINAL. See **magnetostriction, Joule.**

MAGNETOSTRICTION MICROPHONE. See **microphone, magnetostriction.**

MAGNETOSTRICTION, NEGATIVE. The contraction of a material by the application of a **magnetic field.**

MAGNETOSTRICTION OSCILLATOR. See **oscillator, magnetostriction.**

MAGNETOSTRICTION, POSITIVE. The expansion of a material by the application of a **magnetic field.**

MAGNETOSTRICTION, REVERSIBLE. The reversible change in dimensions, resulting from a small cyclic change in applied **magnetic field** superposed on a larger, steady field.

MAGNETOSTRICTION, SATURATION. The limiting value of **magnetostriction** approached as the applied **magnetizing force** is increased indefinitely. Magnetostriction approaches saturation when the magnetization of the material approaches saturation.

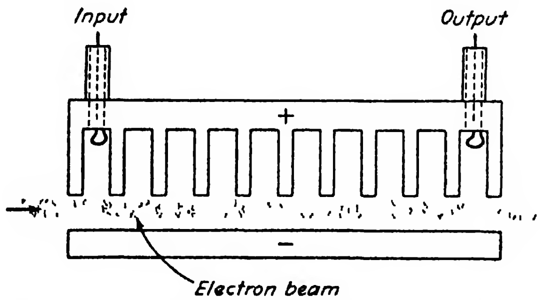
MAGNETOSTRICTION, VOLUME. The change in volume produced by a **magnetic field.**

MAGNETOSTRICTIVE EFFECT, DIRECT. The mechanical strain produced in ferromagnetic rods when placed in a magnetic field

MAGNETOSTRICTIVE EFFECT, INVERSE. The change in the state of magnetization of a ferromagnetic rod when it is subjected to mechanical strain.

MAGNETRON. An **electron tube** characterized by the interaction of electrons with the electric field of a circuit element in crossed, steady electric and magnetic fields to produce a-c power output

MAGNETRON AMPLIFIER. A traveling-wave magnetron (see **magnetron, traveling-wave**) used as an amplifier. The basic features of a typical structure are shown in the figure below It resembles a section of a vane-



Magnetron amplifier structure Magnetic field perpendicular to plane of paper (By permission from "Microwave Theory and Techniques" by Reich et al, Copyright 1953, D Van Nostrand Co. Inc)

type, cavity magnetron of infinite radius, excited at one end, and coupled to a load at the opposite end. A beam of electrons is projected through the space between the plane electrode and the cavity structure, which is maintained at a positive potential relative to the plane electrode. A magnetic field, normal to the plane of the paper, is adjusted so that the electrons do not strike the anode in the absence of alternating field. If the velocity of the electron beam is equal to, or nearly

equal to, the phase velocity with which electromagnetic waves move down the loaded waveguide formed by the cathode and anode, energy is transferred to the electromagnetic wave from the source of direct voltage. The electromagnetic wave that moves from the input resonator to the output resonator, therefore, increases in amplitude, and the power output exceeds the power input.

MAGNETRON, CLEETON AND WILLIAMS. An early **magnetron** having a single anode in which a slit was cut parallel to the cathode. The resonant circuit consisted of small **Lecher frames.** The upper frequency of oscillation was 47,000 megacycles.

MAGNETRON, COAXIAL CYLINDER. A **magnetron** in which the cathode and anode consist of coaxial cylinders. (See **magnetron, cyclotron-frequency.**)

MAGNETRON CUT-OFF. The condition of zero (ideally) **anode current.** Produced by a critical magnetic field strength parallel to the cathode axis, which causes the electrons to travel in a curved orbit of such radius as to miss the anode. The magnitude of the critical magnetic field is proportional to the square root of the anode voltage.

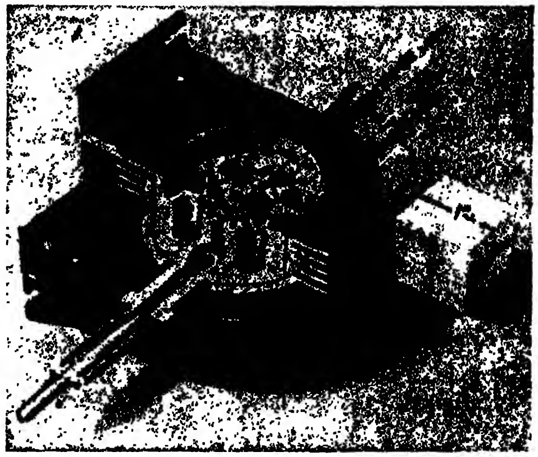
MAGNETRON, CYCLOTRON - FREQUENCY. A **magnetron** whose operation depends upon synchronism between an alternating component of electric field, and a periodic oscillation of electrons in a direction parallel to this field. A split-anode magnetron (see **magnetron, split-anode**) with a resonator connected between the anodes will function as a cyclotron-frequency magnetron oscillator.

MAGNETRON, HULL. The first magnetron, credited to A. W. Hull, which was described in 1921. It was of the coaxial-cylinder type. (See **magnetron, coaxial cylinder.**)

MAGNETRON, INTERDIGITAL. A **magnetron** having axial anode segments around the cathode, alternate segments being connected together at one end, remaining segments connected together at the opposite end.

MAGNETRON, LINEAR OR PARALLEL-PLANE. A theoretical device used because of the mathematical simplification it provides over the coaxial-cylinder magnetron. The anode and cathode are parallel planes of infinite length.

MAGNETRON, MULTICAVITY. A **magnetron** in which the circuit includes a plurality of cavities.



The internal view of a 706AY-GY Magnetron (150 kw, about 3000 mc/s) (By permission from "Radar Systems and Components" by Members of Technical Staff of Bell Telephone Laboratories, Copyright 1949, D. Van Nostrand Co., Inc.)

MAGNETRON, MULTISEGMENT. A **magnetron** with an anode divided into more than two segments, usually by slots parallel to its axis.

MAGNETRON, NEGATIVE-RESISTANCE. A split-anode magnetron (see **magnetron, split-anode**) operated in such a manner as to produce a static, negative-resistance characteristic. If the flux density is approximately the value required to cut off the anode current at the static value of anode voltage, a negative resistance may be found to exist between the two anodes (i.e., the voltage-current curve taken between these two electrodes has a negative shape over a certain region). This negative resistance may be used to cause sustained oscillations, if a **resonator** is connected either in series with one anode segment, or between the two anode segments.

MAGNETRON, OSCILLATOR. See **oscillator, magnetron.**

MAGNETRON OSCILLATIONS, TRAVELING-WAVE. Oscillations sustained by the interaction between the space-charge cloud of a **magnetron** and a traveling electromagnetic field whose **phase velocity** is approximately the same as the **mean velocity of the cloud.**

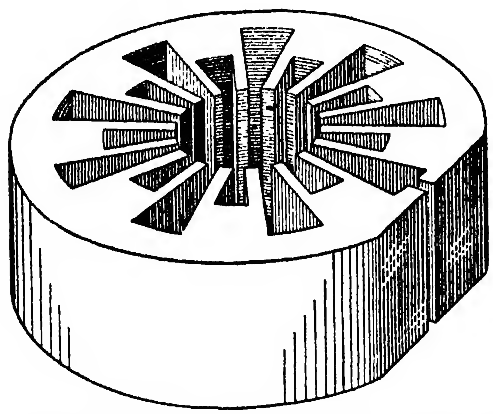
MAGNETRON, PACKAGED. An integral structure comprising a **magnetron,** its magnetic circuit and **output-matching** device.

MAGNETRON PERFORMANCE CHART. A chart relating the applied d-c voltage and current to the magnetic field strength, the power output, and corresponding efficiency. (See **Rieke diagram.**)

MAGNETRON, π-MODE OF OPERATION. The mode of operation of **magnetrons** for which the phases of the fields of successive anode openings facing the **interaction space** differ by π radians.

MAGNETRON RECTIFIER. A cold-cathode, gas diode **rectifier** which is controlled with an external field.

MAGNETRON, RISING-SUN. A multicavity magnetron (see **magnetron, multicavity**)



The "Rising Sun" anode, a scheme for separating the frequencies at which modes may appear (By permission from "Principles and Applications of Waveguide Transmission" by Southworth, Copyright 1950, D. Van Nostrand Co., Inc.)

in which resonators of two different resonance-frequencies are arranged alternately for the purpose of **mode-separation.**

MAGNETRON, SPLIT-ANODE. A **magnetron** with a cylindrical anode divided into two segments, usually by slots parallel to its axis.

MAGNETRON STRAPPING. The connecting together of alternate segments of a multiple-cavity resonator in a **magnetron.** This procedure causes only one mode of oscillation to be preferable, and thus increases stability of operation. (For an illustration of straps, see the figure in definition of **magnetron, multicavity.**)

MAGNETRON, TRAVELING WAVE. A **magnetron** whose operation depends upon interaction of electrons with a traveling electromagnetic field of constant angular or linear velocity. Most present-day magnetrons such as multicavity and multisegment types belong to this class.

MAGNETRONS, TUNING OF. The negative-resistance magnetron and the cyclotron-frequency magnetrons are tuned with conventional resonators external to the device.

Tuning of multicavity magnetrons may be achieved by varying the capacitance or inductance of the cavities.

The resonator-cavity capacitance can be changed by inserting conducting strips (see Figure 1) into the slots in regions where the

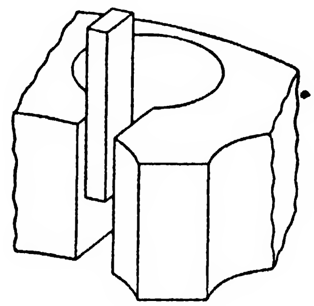


Fig. 1

electric field is high, or by bringing metallic rings, called "C-rings," close to the ends of the resonators at points where the r-f field is high. In "cookie-cutter" tuning (see Figure 2), conducting rings are inserted between straps.

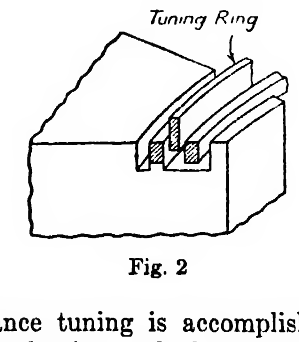


Fig. 2

Inductance tuning is accomplished by inserting conducting rods lengthwise into the resonators in regions where the r-f magnetic field is high, or by moving a conducting disk, called an "L-ring" close to the ends of the

resonator near their radially outermost points, where the r-f magnetic field is high. The rod

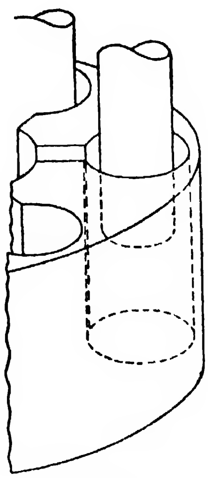


Fig. 3

type of tuning is called "sprocket tuning" or "crown-of-thorns" tuning (see Figure 3).

MAGNETTOR. A second-harmonic type of **magnetic modulator.**

MAGNIFICATION. The ratio of the size of an image formed by an optical system to the size of the object is the most frequent meaning of magnification. However, for a large and distant object, the ratio at the eye of the angle subtended by the image to the angle which would be subtended at the eye by the object itself is also called magnification although it is better stated as **magnifying power.**

MAGNIFICATION, ANGULAR. See **angular magnification.**

MAGNIFICATION, EMPTY. See **empty magnification.**

MAGNIFICATION, LATERAL. See **lateral magnification.**

MAGNIFICATION, LINEAR. See **linear magnification.**

MAGNIFICATION, LONGITUDINAL. See **longitudinal magnification.**

MAGNIFICATION, NORMAL. See **normal magnification.**

MAGNIFICATION, OPTIMUM. See **optimum magnification.**

MAGNIFICATION, USEFUL. Discussed under **empty magnification.**

MAGNIFIER. If an object is held somewhat closer to a thin, **positive lens** than its principal **focal point** and viewed through the lens, an enlarged erect **virtual image** will be seen. Used this way the lens is a simple magnifier. To reduce the **aberrations** of high magnification, magnifiers are commonly made of two or more lenses. These are also called **oculars.**

MAGNIFYING POWER. Crudely defined, the magnifying power of an optical instrument is the ratio of the apparent size of an object as seen through the instrument to the apparent size of the same object as seen without the instrument. However, to define "apparent size of an object" in terms that will permit of rigorous discussion requires certain assumptions. One may define the apparent size of an object as the angle which the object subtends at the eye, or as the size of the image which the lens of the eye forms of the object on the retina of the eye (retinal image). Even with this definition of apparent size, the term magnifying power depends upon the type of instrument which is under consideration, and the eyepieces used with it.

MAG-SLIP. A British term for a **synchro.**

MAIN BANG. Transmitted **pulse,** within a **radar** system.

MAIN GAP (OF A GLOW-DISCHARGE COLD-CATHODE TUBE). See **gap, main (of a glow-discharge cold-cathode tube).**

MAJOR CYCLE. In a memory device which provides serial access to storage positions, the time interval between successive appearances of a given storage position.

MAJOR LOBE (BEAM). See **lobe, major (beam).**

MAJORANA FORCE. Postulated phenomenological force between two nucleons derivable from a potential in which there appears an **operator** exchanging the positions of the particles but not their spins.

MAJORANA PARTICLE. Neutrino which is identical with the **antineutrino,** so that **double beta decay** could occur with the emission and absorption of a neutrino rather than the emission of two neutrinos.

MAJORITY CARRIER (IN A SEMICONDUCTOR). The type of **carrier** constituting more than half of the total number of carriers.

MAKSUTOV CORRECTOR. The complicated aspherical surfaces of the **Schmidt corrector** can be avoided, and excellent correction still be retained by putting a thick-meniscus **lens** having spherical surfaces of approximately equal **radii of curvature** in front of a spherical mirror.

MALLEABILITY. The property by which a material may be hammered out or rolled into shape without tearing or fracture, or the extent to which a material possesses that property.

MALUS COSINE-SQUARED LAW. A law applying to the intensity of **polarized light** as affected by the polarizing apparatus. If a beam of plane-polarized light is passed through a **nicol prism,** for example, the intensity (flux density) of the emergent beam falls off, as the prism is rotated, from a maximum value when the transmission plane of the prism coincides with the plane of vibration of the light, to zero when it is at right angles to that direction. The intensity varies as the square of the cosine of the angle through which the prism has been thus rotated. The same law applies to the effect of a glass reflector, reflecting always at the polarizing angle, as the plane of reflection is rotated around the stationary, polarized incident beam

MALUS, LAW OF. An **orthotomic system** of rays remains orthotomic after any number of refractions and reflections.

MANGANESE. Metallic element Symbol Mn. Atomic number 25

MANGANIN. An alloy of copper, manganese and nickel, widely used for precision resistors. It has high **resistivity,** low temperature coefficient, good stability, and exhibits only a small thermal emf at junctions with copper.

MANGIN MIRROR. By silvering the second (convex) of a **Maksutov corrector** plate with somewhat different radii of curvature for its two spherical surfaces, a good degree of correction is obtained for a spherical mirror. This makes **a catadioptric system.**

MANIFESTLY COVARIANT. Obviously covariant. Written in terms of four-vectors, tensors and Lorentz invariant operators and numbers, in such a way that consistency with the special theory of relativity (see **relativity theory, special**) is apparent at a glance.

MANIFOLD OF ELECTRONIC STATES. The sum or totality of the electronic terms of an atom or molecule.

MANOCRYOMETER. An instrument invented by de Visser to determine the change in the melting point of a substance due to change in pressure. It consists of a thick-walled thermometer inverted, with the capillary stem bent upward and then at right angles. The substance under observation is placed in the bulb, and mercury is admitted to the capillary. The whole is then placed in a thermostat, when it assumes the pressure (measured by the mercury) of equilibrium between solid and liquid in the bulb.

MANOMETER. An instrument for measuring pressure. Usually, some form of liquid manometer, using the pressure produced by a liquid column to balance the pressure to be measured.

MANOMETER, DIFFERENTIAL. An instrument for measuring differences of pressure

MANOMETER, HOT-WIRE. A device for measuring pressures through the determination of the rate of heat loss from an electrically heated wire. (See **gauge, Pirani.**)

MANOMETER, INCLINED-TUBE. A form of liquid manometer in which the liquid head balancing the pressure to be measured is produced by a column of liquid in a tube making a small angle with the horizontal. The movement of liquid for a given change in pressure may be increased in this way by a ratio of more than ten compared with a similar manometer with the tube vertical.

MANOMETER, IONIZATION. See **gauge ionization.**

MANOMETER, TWO-FLUID. A design of **manometer** in which the pressure difference is balanced against the **head** caused by the vertical movement of the interface between two liquids of nearly equal density. Compared with a simple manometer, the sensitivity is increased roughly in the ratio of the mean density to the density difference. One example is the **Chattock gauge.**

MANTISSA. The decimal part of a common logarithm. (See **logarithm, common.**)

MANY-BODY FORCE. An interaction between two particles that becomes modified when a third particle is present, e.g., the forces between polarizable molecules.

MAP. Suppose that for every point x in a given space or coordinate system A there is another point (or points) represented by $f(x)$ in the space or system B, then there is a **map** or mapping $f(x)$ of A into B. The point $f(x)$ is the **image** or **transformation** of x.

MARKER ANTENNA. See **antenna, marker.**

MARKER BEACON. A low-power transmitter placed along established airline routes for guidance purposes.

MARKER PIP. An identification **pulse** which is superimposed on some form of cathode-ray tube display to indicate the position of a definite frequency, time or phase.

MARKING WAVE (KEYING WAVE). In telegraphic communication, the emission which takes place while the active portions of the code characters are being transmitted.

MARTENS POLARIZATION PHOTOMETER. See **photometer, Martens polarization.**

MARTENS WEDGE. A type of quartz wedge rotator for polarized light

MARX EFFECT. The reduction in the energy of a **photoelectric emission** by the simultaneous incidence of radiation of lower frequency than that producing the emission; a regressive effect.

MASK MICROPHONE. See **microphone, mask.**

MASKING (AUDIO). The amount by which the threshold of audibility (see **audibility, threshold of**) of a sound is raised by the presence of another (masking) sound. The unit customarily used is the **decibel.**

MASKING AUDIOGRAM. See **audiogram, masking.**

MASS. The physical measure of the principal inertial property of a body, i.e., its resistance to change of motion. At speeds small compared with the speed of light, the mass of a body is independent of its speed. Under these circumstances, the masses m_1 and m_2 of two bodies may be compared by allowing the two bodies to interact. Then

$$m_1/m_2 = |a_2|/|a_1|,$$

where $|a_1|$ and $|a_2|$ are the magnitudes of the respective accelerations of the two bodies as a result of the interaction. This permits the measurement of the mass of any particle with respect to a standard particle (for example, the standard kilogram). At higher speeds, the mass of a body depends on its speed relative to the observer according to the relation:

$$m = m_0/\sqrt{1 - v^2/c^2}$$

where m_0 is the mass of the body as found by an observer at rest with respect to the body, v is the speed of the body relative to the observer who finds its mass to be m, and c is the speed of light in empty space (**theory of relativity**).

As a consequence of the Newton law of universal gravitation or of the Einstein demonstration of the equivalence of inertial and gravitational masses, equal masses at the same location in a gravitational field have equal weights. Because of this, masses may be compared with a platform balance or a spring balance.

Mass is particularly important because it is a conserved quantity, which can neither be created nor be destroyed. Thus, the mass of any isolated system is a constant. When relativistic mechanics is appropriate, e.g., when speeds comparable to the speed of light are involved, mass may be converted into energy and *vice versa*, hence the energy of the system must be converted into mass through the Einstein equation.

$$E = mc^2$$

where c is the speed of light in empty space, before the conservation law may be applied.

MASS ABSORPTION COEFFICIENT. See discussion of **absorption coefficient;** also see **absorption coefficient, mass.**

MASS, ACOUSTIC (ACOUSTIC INERTANCE). The quantity which, when multiplied by 2π times the frequency, gives the acoustic reactance (see **reactance, acoustic**) associated with the kinetic energy of the medium.

MASS ANALYZER, TROCHOIDAL. A mass **spectrometer** wherein the ion beams traverse trochoidal paths within electric and magnetic fields mutually perpendicular.

MASS, CENTER OF. The center of mass is that point in a collection of mass-particles which moves as if the total mass of the collection were concentrated there and the resultant of all the external forces were acting there. The position vector of such a point is given by

$$\bar{\mathbf{r}} = \frac{\sum_{i=1}^{n} m_i \mathbf{r}_i}{\sum_{i=1}^{n} m_i}$$

where m_i is the mass of ith discrete particle, $\mathbf{r}_i$ is the position vector of ith discrete particle

For a rigid continuous body, the rectangular coordinates of the center of mass are written as

$$\bar{x} = \frac{\int x dm}{\int dm}$$

$$\bar{y} = \frac{\int y dm}{\int dm}$$

$$\bar{z} = \frac{\int z dm}{\int dm}.$$

MASS, CONSERVATION OF. See **mass, law of**; and **mass**.

MASS DEFECT. The difference between the **atomic mass** and the **mass number** of a nuclide. (See **packing fraction.**)

MASS-ENERGY EQUIVALENCE. The equivalence of a quantity of mass and a quantity of energy when the two quantities are related by the equation, $E = mc^2$. The conversion factor c^2 is the square of the velocity of light. The relationship was developed from **relativity theory,** but has been experimentally confirmed.

MASS-ENERGY RELATION. The equation $E = mc^2$. (See **mass-energy equivalence.**)

MASS FORMULA. An equation for the atomic mass of a nuclide as a function of its **atomic number** and **mass number.** (See **mass formula, empirical** and **mass formula, semiempirical.**)

MASS FORMULA, EMPIRICAL. A formula for the mass of an atom of the form:

$$M(A,Z) = A(1 + f_A) + \tfrac{1}{2}B_A(Z - Z_A)^2 + \Delta,$$

where M is the mass of an atom of atomic number Z and mass number A; f_A is an idealized packing fraction; Z_A is the (nonintegral) atomic number of maximum stability for mass number A; and Δ is a term reflecting the "pairing energy" of like nucleons, and therefore having four possible values which are

$$\Delta = \begin{cases} +\tfrac{1}{2}\delta_A \text{ for even } A, \text{ odd } Z \\ +\tfrac{1}{2}\epsilon_A \text{ for odd } A, \text{ odd } Z \\ -\tfrac{1}{2}\epsilon_A \text{ for even } A, \text{ odd } Z \\ -\tfrac{1}{2}\delta_A \text{ for even } A, \text{ odd } Z \end{cases}.$$

The terms δ_A, ϵ_A, as well as f_A, B_A and Z_A are usually taken to be parameters varying smoothly with A, which are adjusted to fit the experimental data.

MASS FORMULA, SEMIEMPIRICAL. A mass formula (due principally to von Weizsacker, Bethe, Becker, Bohr and Wheeler) based on the liquid-drop model of the nucleus It may be written:

$$\begin{aligned} M(A,Z) = {} & ZM_H + (A - Z)M_n \\ & - aA + b\frac{(A - 2Z)^2}{A} \\ & + 4\pi c r_0{}^2 A^{2/3} \\ & + \frac{3Z(Z - 1)e^2}{5r_0 A^{1/3}} + \Delta. \end{aligned}$$

Here $M(A,Z)$ is the mass of an atom of mass number A and atomic number Z, M_H and M_n are the masses of the hydrogen atom and the neutron, e is the electronic charge, r_0 is the radius parameter, and a, b and c are adjustable parameters. The terms represent, in order: the mass of the constituent protons and electrons; the mass of the constituent neutrons; the "bulk energy of condensation" due

to short-range attractive forces between nucleons; the "asymmetry energy" corresponding to the tendency of protons and neutrons to be equal in number; the "surface energy"; the "electrostatic energy" due to repulsive forces between protons; and the "pairing energy" as given under **mass formula, empirical.**

MASS, LAW OF CONSERVATION OF. See **conservation of mass, law of;** and **mass.**

MASS NUMBER. The whole number nearest in value to the atomic mass when that quantity is expressed in atomic mass units. In light of present-day theory, the mass number represents the total number of nucleons in the nucleus, and is therefore equal to the sum of the **atomic number** and the **neutron number.** The mass number is commonly written as a superscript after or before the symbol of the atom, such as O^{16} or a ^{40}K.

MASS OF THE UNIVERSE. A quantity of order $M \sim \rho c^3 T^3$, where ρ is the density of matter in the universe and T is the age of the universe. M is of order 10^{55} g, or about 10^{79} times the mass of a nucleon.

MASS OPERATOR. Operator added to the **Lagrangian** of a **quantized field theory** in order to cancel out certain divergences. Combines with the term representing the **mechanical mass** to give the observed mass (See **renormalization of mass.)**

MASS RADIATOR. A source of electromagnetic radiation covering a broad band extending to extremely high frequencies, which consists of metal particles suspended in a liquid dielectric. A high voltage impressed across the dielectric produces sparking between the particles, thus releasing the radiation.

MASS RANGE. See **range.**

MASS SPECTROGRAM. The photograph of a **mass spectrum.**

MASS SPECTROGRAPH. Any type of apparatus for sorting streams of electrified particles in accordance with their different masses by means of deflecting fields.

MASS SPECTROGRAPH, ASTON POSITIVE RAY. A device which utilizes successive electric and magnetic fields to focus rays of a constant **charge-to-mass ratio** at a focal line.

MASS SPECTROGRAPH, BAINBRIDGE-JORDAN. A **mass spectrograph** using a radial electrostatic field of $\pi/\sqrt{2}$ radians and a magnetic field deflecting the ions through 60 degrees. The two fields are so disposed that the dispersion of ions in the electric field is exactly compensated by the dispersion in the magnetic field for a given velocity difference.

MASS SPECTROGRAPH, BLEAKNEY. A **mass spectrograph** which makes use of crossed electric and magnetic fields which permits perfect focusing properties; the focusing depends only on the **charge-to-mass ratio** of the ion and not on its velocity or direction.

MASS SPECTROGRAPH, DEMPSTER (DIRECTION FOCUSING). A **mass spectrograph** in which ions are first accelerated by an electric field through a slit, and are then deflected by a magnetic field so as to pass through a second slit. The direction focusing consists of the fact that ions of the same **charge-to-mass ratio** are made to pass through the second slit regardless of their direction when they emerge from the first slit.

MASS SPECTROGRAPH, NIER. A **mass spectrograph** in which ions are initially accelerated to a given velocity and are then bent in a magnetic field so that ions of a given **charge-to-mass ratio** characteristic of the initial velocity are the only ones focussed.

MASS SPECTROGRAPH, TIME OF FLIGHT. A **mass spectrograph** in which ions are given a fixed **impulse** and are then allowed to move in circular paths in a magnetic field. Particles of different **charge-to-mass** ratio traverse their paths in different times

MASS SPECTROGRAPH, VELOCITY FOCUSING. A **mass spectrograph** in which positive ions passing through two slits are acted upon by opposing electric and magnetic fields. If the velocity v of the ions is equal to E/H (ratio of electric to magnetic field strengths), then the ions are undeflected by the fields and pass through a third slit into another magnetic field where they are deflected into a semicircular path. The radius of curvature of this path is then proportional to the **charge-to-mass ratio** of the ions.

MASS SPECTRUM. See **spectrum, mass.**

MASSEY FORMULA. A formula which gives the probability of secondary electron emission by an excited atom approaching a metallic surface.

MASSIVE COIL. The coil which carries the input current in a photoelectric recording galvanometer (see **galvanometer, recording**) and whose motion is duplicated by the slave coil.

MASTER. The negative phonograph record made by electroplating a thin layer of copper and nickel on the wax original.

MASTER BRIGHTNESS CONTROL. The common **bias** control for all three electron-guns of a three-color **kinescope.**

MASTER OSCILLATOR. See **oscillator, master.**

MASTER OSCILLATOR-POWER AMPLIFIER. Frequently abbreviated MOPA, a master oscillator and a succeeding buffer amplifier. (See **oscillator, master** and **amplifier, buffer.**)

MATCHED POWER GAIN. The power gain achieved when the **load impedance** is matched to the effective output impedance of the driving stage (See **gain-band merit.**)

MATCHED TERMINATION (FOR A WAVEGUIDE). A **termination** producing no reflected wave at any transverse section of the **waveguide.**

MATCHED TRANSMISSION LINE. See **waveguide, matched.**

MATCHED WAVEGUIDE. See **waveguide, matched.**

MATCHING, IMPEDANCE. The technique of minimizing the **standing-wave ratio** when two devices having unlike **impedances** are coupled together. This process, at the same time, maximizes power flow between the two devices, assuming one to be a source and the other a sink. (See also **image impedance.**)

MATERIAL PARTICLE. See **particle, material.**

MATERIALIZATION. The production of matter from energy radiations, as is believed to occur in interstellar space, and in certain recent investigations, from high-frequency γ-rays, which are transformed into electron-positron pairs. (See **pair production.**)

MATHIEU EQUATION. A **differential equation** resulting from the separation, in **elliptical cylindrical coordinates,** of **partial differential equations** like **Laplace's** or the **wave equation.** It also occurs in the quantum mechanical problem of a molecule with restricted internal rotation. The usual form of the equation is

$$y'' + (a + b \cos 2x)y = 0$$

but related forms are sometimes given Since the coefficient of y is periodic, the **Floquet theorem** applies and possible solutions are

$$y = e^{\mu x}P(x),$$

where $P(x)$ is periodic and can be written as an infinite series of sine or cosine terms. Substitution of this assumed solution into the differential equation gives a three-term **recursion formula** for the coefficients in the series The exponent μ is obtained as a complicated function of the parameters a and b, which may be written as a **continued fraction** or as **Hill's determinant.** If the final solution is required to be periodic, a situation occurring frequently for physical reasons, $\mu = ik$, with k an integer. The allowed values of a are the **eigenvalues** and the solutions are **Mathieu functions** of the first kind. A second linearly independent solution, called a function of the second kind, is not periodic.

Associated Mathieu functions arise when x is replaced by ix They can be expressed as series in **Bessel** and **Hankel functions.**

MATRIX. (1) Consider a set of elements, finite in number, which may be arranged in rows and columns. If A_{ij}, B_{ij} are the elements in the ith row and jth column of two such arrays and if these arrays combine to form a **product** with elements $C_{ij} = \Sigma A_{ik}B_{kj}$ then they are called **matrices.** Matrices are conveniently indicated by the symbols **A**, **B**, **C** and their product by **C** = **AB**. A matrix containing m rows and n columns is of **order** $(m \times n)$. **Matrix elements** may be real, complex or imaginary quantities of a very general nature. The ideas may be extended to include matrices of infinite order.

(2) In color television, either (a) an array of the coefficients symbolic of an operation to be performed, which operation results in a

color-coordinate transformation; or (b) to perform a color-coordinate transformation by computation, or by electrical, optical or other means.

MATRIX, ADJOINT. If A^{ij} is the cofactor of A_{ij} in $|\mathbf{A}|$, the determinant of the square matrix $\mathbf{A}$, the matrix $\hat{\mathbf{A}} = [A^{ji}]$ is called adjoint to $\mathbf{A}$ The nomenclature is not unique for this matrix is sometimes called the adjugate or given no name at all while adjoint is applied by some writers to that matrix here called **associate.** Its properties include

$$\mathbf{A}\hat{\mathbf{A}} = \hat{\mathbf{A}}\mathbf{A} = |\mathbf{A}|\mathbf{E}$$

where $\mathbf{E}$ is the unit matrix. If $\mathbf{A}$ is singular then

$$\mathbf{A}\hat{\mathbf{A}} = \mathbf{O}$$

where $\mathbf{O}$ is the null matrix.

MATRIX, ASSOCIATE. Defined by $\mathbf{A}^{\dagger} = (\widetilde{\mathbf{A}^{*}}) = (\tilde{\mathbf{A}})^{*}$ where $\tilde{\mathbf{A}}$ is the transpose of $\mathbf{A}$ and $\mathbf{A}^{*}$, the complex conjugate of $\mathbf{A}$. If $\mathbf{X} = \mathbf{ABC}$, $\mathbf{X}^{\dagger} = \mathbf{C}^{\dagger}\mathbf{B}^{\dagger}\mathbf{A}^{\dagger}$. Frequently called the Hermitian conjugate. (See also **matrix, adjoint.**)

MATRIX, CONFORMABLE. Two matrices $\mathbf{A}$ and $\mathbf{B}$ are **conformable** if the number of columns in $\mathbf{A}$ equals the number of rows in $\mathbf{B}$. If their **orders** are $(n \times h)$, $(h \times m)$, respectively, their product $\mathbf{C} = \mathbf{AB}$ is of order $(n \times m)$. Two or more matrices may be combined to give a product only if they are conformable

MATRIX, COMMUTATIVE. If the product of two matrices $\mathbf{A}$ and $\mathbf{B}$ is independent of the order of multiplication so that $\mathbf{AB} = \mathbf{BA}$, then $\mathbf{A}$ and $\mathbf{B}$ are **commutative.** If they do not commute the quantity $\mathbf{AB} - \mathbf{BA}$ is called the **commutator.**

MATRIX, COMPLEX CONJUGATE. Formed by taking the **complex conjugate** of every element of $\mathbf{A}$ and frequently identified by $\mathbf{A}^{*}$. The operation involved is commutative, for if $\mathbf{X} = \mathbf{ABC}$; $\mathbf{X}^{*} = \mathbf{A}^{*}\mathbf{B}^{*}\mathbf{C}^{*}$. (See **matrix, real** and **matrix, pure imaginary.**)

MATRIX, DIAGONAL. All elements are zero except those on the main diagonal, or symbolically, $\mathbf{D} = [D_i\delta_{ij}]$ where δ_{ij} is the **Kronecker delta.** The notation $\mathbf{D} = diag\ (D_1, D_2, D_3, \cdots)$ is also used. If $\mathbf{D}$ and $\mathbf{D}'$ are two diagonal matrices $\mathbf{DD}' = \mathbf{D}'\mathbf{D}$. Conversely if $\mathbf{D}$ is diagonal, not the unit matrix, and $\mathbf{DA} = \mathbf{AD}$ then $\mathbf{A}$ is also diagonal. If $\mathbf{A}_1, \mathbf{A}_2, \mathbf{A}_3, \cdots$ are matrices of order greater than unity, the form $\mathbf{W} = diag\ (A_1, A_2, A_3, \cdots)$ means that the matrices $\mathbf{A}_i$ are placed along the main diagonal and all other elements of $\mathbf{W}$ are zero.

MATRIX, DIAGONALIZATION OF A. A process for transforming an arbitrary matrix $\mathbf{A}$ into a diagonal matrix The transformation is usually of the form $\mathbf{X}^{-1}\mathbf{AX} = \mathbf{D} = D_i\delta_{ij}$, where δ_{ij} is the **Kronecker delta.** Hermitian and symmetric matrices may always be diagonalized by a **unitary matrix**; in the general case, the transforming matrix is composed of the eigenvectors of $\mathbf{A}$, provided the eigenvalues are all different. If the eigenvalues are repeated, a diagonal form is not obtained but a **triangular matrix** results.

MATRIX, DIRECT PRODUCT OF A. If $\mathbf{A} = [A_{ij}]$ is a square matrix of order m and $\mathbf{B} = [B_{rs}]$ is square of order n, the direct product is of order $m \times n$

$$\mathbf{A} \times \mathbf{B} = [A_{ij}B_{rs}].$$

The index pairs (i,j) and (r,s) refer to the row and column respectively. Some convention must be arbitrarily adopted for arranging the elements in the rows and columns.

MATRIX ELEMENT. A quantity A_{ij} at the intersection of the ith row and the jth column of a **matrix.** It may be of a general functional nature, real or complex.

MATRIX, EQUIVALENT. If $\mathbf{X}$ and $\mathbf{Y}$ are non-singular matrices, then $\mathbf{A}$ and $\mathbf{B}$ are equivalent if $\mathbf{B} = \mathbf{XAY}$ and $\mathbf{B}$ is then the **transform** of $\mathbf{A}$. If $\mathbf{X}$ and $\mathbf{Y}$ are properly chosen, $\mathbf{B}$ may be of simpler form than $\mathbf{A}$, diagonal for example. Usually $\mathbf{X} = \mathbf{Y}^{-1}$.

MATRIX, HERMITIAN. A matrix of such nature that $\mathbf{H} = \mathbf{H}^{*}$; that is $H_{ij} = H_{ji}^{*}$ where the asterisk designates the **complex conjugate.** A **real symmetric matrix** is a special case for if $\mathbf{H} = \mathbf{A} + i\mathbf{B}$, $\mathbf{H}^{*} = \mathbf{A} - i\mathbf{B}$ where the real part, $\mathbf{A}$, is symmetric and the imaginary part, $\mathbf{B}$, is skew symmetric.

MATRIX, INVOLUTARY. A matrix of such nature that $\mathbf{A} = \mathbf{A}^{-1}$, where the latter is the **reciprocal** of the former.

MATRIX, INVERSE. Same as **matrix, reciprocal.**

MATRIX MECHANICS. See **Heisenberg representation; quantum mechanics.**

MATRIX, NILPOTENT. Some power of the matrix vanishes, $\mathbf{A}^n = 0$.

MATRIX, NORMAL. A square matrix which satisfies the condition $\mathbf{AA}^* = \mathbf{A}^*\mathbf{A}$, where $\mathbf{A}^*$ is the **associate** of $\mathbf{A}$ (or the **transpose** if $\mathbf{A}$ is real). Any normal matrix can be transformed to **diagonal** form by a **unitary matrix** and, conversely, any matrix transformable to diagonal form by a unitary matrix is normal.

MATRIX, NULL. Every element is zero. The usual symbol is $\mathbf{0}$. For any matrix $\mathbf{A0} = \mathbf{0A} = \mathbf{0}$ and $\mathbf{0} + \mathbf{A} = \mathbf{A}$.

MATRIX, ORTHOGONAL. Symbolized by $\mathbf{A} = \tilde{\mathbf{A}}^{-1}$ where $\tilde{\mathbf{A}}$ is the transposed matrix and $\mathbf{A}^{-1}$ is the reciprocal of $\mathbf{A}$. Its matrix elements must be so related that

$$\Sigma A_{is}A_{js} = \Sigma A_{si}A_{sj} = \delta_{ij}$$

From its definition, $\mathbf{A}\tilde{\mathbf{A}} = \mathbf{E}$, where $\mathbf{E}$ is the unit matrix and the square of its determinant, $|\mathbf{A}|^2$, is one. In three dimensions, the case $|\mathbf{A}| = +1$ may refer to a proper rotation, that is, a rotation about a rectangular Cartesian coordinate axis by an angle ϕ, $|\mathbf{A}| = -1$, an improper rotation, a proper rotation followed by a reflection in a plane perpendicular to the axis of rotation.

MATRIX, PARTITIONED. A matrix divided into two or more submatrices. Each element of the partitioned matrix, although itself a matrix, is indicated by a single symbol and treated as if it were a single element.

MATRIX, PERMUTATION. Each row and column has but one non-zero element and that is unity. Transformation by such a matrix permutes the order of the rows and the columns of the matrix transformed.

MATRIX, PRODUCT. See **matrix; matrix, conformable; matrix, direct product.**

MATRIX, PURE IMAGINARY. The matrix elements are iA_{jk} where A_{jk} is real. It follows that $\mathbf{A} = -\mathbf{A}^*$, where $\mathbf{A}^*$ is the **complex conjugate to A.**

MATRIX, RANK OF A. See **rank.**

MATRIX, REAL SYMMETRIC. The element in the ith row and the jth column equals the element in the jth row and the ith column, $A_{ij} = A_{ji}$ and $\mathbf{A} = \tilde{\mathbf{A}}$, where $\tilde{\mathbf{A}}$ is the **transposed** matrix.

MATRIX, RECIPROCAL. If $\mathbf{A}$ is not a singular matrix, the reciprocal is defined by

$$\mathbf{A}^{-1} = \frac{\hat{\mathbf{A}}}{|\mathbf{A}|}$$

where $\hat{\mathbf{A}}$ is the adjoint matrix, $|\mathbf{A}|$ is the determinant of $\mathbf{A}$. Its properties include $\mathbf{A}^{-1}\mathbf{A} = \mathbf{AA}^{-1} = \mathbf{E}$, with $\mathbf{E}$ the unit matrix, but reciprocation of the matrix product requires reversal of the order of the factors: $\mathbf{C} = \mathbf{AB}$; $\mathbf{C}^{-1} = \mathbf{B}^{-1}\mathbf{A}^{-1}$. Also called **inverse matrix.**

MATRIX, RECTANGULAR. Containing m rows and n columns, $m \neq n$. It is always **singular,** since by definition its determinant vanishes.

MATRIX, ROW. A matrix containing one row and n columns. The matrix elements are usually considered as the components of a **vector** in n-dimensional space.

MATRIX, SINGULAR. A matrix whose **determinant** vanishes, $|\mathbf{A}| = 0$. All **rectangular matrices** are singular. If the determinant is not zero, the matrix is nonsingular.

MATRIX, SKEW HERMITIAN. See **matrix, Hermitian.** The matrix elements are $A_{ij} = -A_{ji}^*$, $A_{ii} = 0$ and $\tilde{\mathbf{A}} = -\mathbf{A}^*$, where $\mathbf{A}^*$ is the matrix **associate** to $\mathbf{A}$.

MATRIX, SKEW SYMMETRIC. See **matrix, symmetric.** The imaginary part of an **Hermitian matrix.** If $\tilde{\mathbf{A}}$ is the **transpose of A,** then a skew symmetric matrix is defined by $\mathbf{A} = -\tilde{\mathbf{A}}$. Its elements are $A_{ij} = -A_{ji}$, $A_{ii} = 0$.

MATRIX, SYMMETRIC. The elements are symmetric about the main diagonal, $A_{ij} = A_{ji}$ and $\mathbf{A} = \tilde{\mathbf{A}}$, where $\tilde{\mathbf{A}}$ is the transposed matrix.

MATRIX, SQUARE. It contains n^2 elements and has an equal number of rows and columns.

MATRIX, TRACE OF A. See **trace.**

MATRIX, TRANSPOSED. Obtained by interchanging the rows and columns of the ma-

trix. If the elements of $\mathbf{A}$ are A_{ij}, the elements of its transpose, $\tilde{\mathbf{A}}$ are A_{ji}. If $\mathbf{X} = \mathbf{ABCD}$, $\tilde{\mathbf{X}} = \tilde{\mathbf{D}}\tilde{\mathbf{C}}\tilde{\mathbf{B}}\tilde{\mathbf{A}}$.

MATRIX, TRIANGULAR. All elements below the principal diagonal vanish.

MATRIX, UNIT. Its elements are the **Kronecker delta,** δ_{ij}, and are unity along the main diagonal and zero elsewhere. Frequently symbolized by **E** (for the German *"einheit"*) its properties include **EA** = **AE** = **A**, where **A** is any matrix.

MATRIX, UNITARY. The complex analogue of an **orthogonal matrix.** If U, U† and U^{-1} are **unitary, Hermitian** and **reciprocal** respectively, then $U - (U^{\dagger})^{-1}$ and its elements satisfy the equation

$$\Sigma U_{ik}U_{jk}^* = \Sigma U_{ki}^*U_{kj} = \delta_{ij}$$

where δ_{ij} is the **Kronecker delta** and the asterisk denotes the **complex conjugate.**

MATRIXER (MATRIX UNIT, MATRIX CIRCUIT, ETC.). A device which performs a color-coordinate transformation by electrical, optical or other means.

MATTER. From the classical macroscopic point of view, that which can be considered as an aggregate of material particles. It is capable of being located in public space and public time and possesses the inherent property of **inertia.** Its manifold other properties and its structure form the subject matter of physics.

MATTER, ANNIHILATION. Transformation of matter into energy.

MATTHIESSEN RULE. An approximate rule stating that the total electrical or thermal resistivity of a metal is the sum of the separate resistivities due to scattering of the electrons by thermal vibrations of the lattice, by impurities, by imperfections, etc. (See **conductivity, electrical,** and **thermal conduction in solids.**)

MAXIMUM. If a function $y = f(x)$ at some point x_0 has a value algebraically greater than all values in the immediate neighborhood of this point, it has a **maximum** there. If the curve of the function is studied, the behavior of its slope or **derivative** will reveal the presence of a maximum. The requirement, if y is continuous at $x = x_0$, is $dy/dx < 0$ for $x > x_0$; $dy/dx > 0$ for $x < x_0$. If dy/dx changes sign by becoming infinite and y becomes infinite at the same time, then $f(x)$ is **discontinuous** and the function has no maximum. Another possibility for a change in sign of the derivative is a **minimum.** The neutral term **extremal** is often used. The phenomena also occur for functions of several variables. (See **minimax, saddle point, Lagrange multiplier.**)

MAXIMUM AVERAGE POWER OUTPUT. Refer to entry for **power output, maximum average.**

MAXIMUM BOILING POINT. A two-component or multi-component liquid system in which, for a particular composition, the boiling point is higher than that for any other composition or for the pure components is said to have a maximum boiling point at that temperature.

MAXIMUM-DEVIATION SENSITIVITY (IN FM RECEIVERS). See **sensitivity, maximum-deviation (in FM receivers).**

MAXIMUM FREEZING POINT. A two-component or multi-component liquid system in which, for a particular composition, the freezing point is higher than that for any other composition or for the pure **components** is said to have a maximum freezing point at that temperature

MAXIMUM MULTIPLICITY, RULE OF. An empirical statement that the energy of **interaction** between the electrons in any one atom is at a minimum when their resultant **spin** is greatest

MAXIMUM OUPUT (IN RECEIVERS). The greatest average output power (see **power output, maximum average**) into the rated load, regardless of **distortion.**

MAXIMUM RANGE. See **range.**

MAXIMUM SOUND PRESSURE. See **sound pressure, maximum.**

MAXIMUM UNDISTORTED OUTPUT (MAXIMUM USEFUL OUTPUT). For sinusoidal input, the greatest average output power (see **power output, maximum average**) into the rated load with distortion not exceeding a specified limit.

MAXIMUM USABLE FREQUENCY. See **frequency, maximum usable.**

MAXWELL. A unit of **magnetic flux** in the **emu system** of units. It is the **magnetic flux** which, when linked with a single turn, generates an electromotive force of 1 abvolt in the turn, as it (the magnetic flux) decreases uniformly to zero in 1 second.

MAXWELL-BOLTZMANN DISTRIBUTION LAW. An expression giving the distribution of velocities among the molecules of a perfect gas in the steady state:

$$N(c) = 4\pi N\left(\frac{m}{2\pi kT}\right)^{3/2} c^2 e^{-\frac{mc^2}{2kT}},$$

where $N(c)$ is the number of molecules with velocities between c and $c + dc$, N, the total number of molecules, m, the mass of a molecule, k, Boltzmann's constant, and T, the absolute temperature.

MAXWELL COLOR TRIANGLE. See **color.**

MAXWELL DEMON. An imaginary figure pictured by Maxwell to illustrate a concept in gas kinetics A tiny being was considered to operate a trap door in a partition between two chambers This "demon" opened the door whenever a molecule of a particular kind approached the door, and so effected separation of a pure gas from a mixture

MAXWELL EQUATIONS. A set of four classic formulae of the **electromagnetic theory.** They deal with certain vector quantities pertaining to any point of a region under varying electric and magnetic influence. If the point is in empty space, the equations are somewhat simplified; in general, provision must be made for the presence of dielectrics, conductors, or magnetizable bodies. In these equations, **H** is **magnetizing force, B** is **magnetic induction, E** is **electric intensity, D** is **electric induction,** ρ is **electric charge density, J** is **conduction current density,** t is time The **"curl"** and the **"divergence"** of a function are well-known operators of vector analysis. The equations, in rationalized mks units, are

$$\text{Curl } \mathbf{H} = \frac{\partial \mathbf{D}}{\partial t} + \mathbf{J}$$

$$\text{Curl } \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}.$$

The additional relations

$$\text{Div } \mathbf{B} = 0$$

$$\text{Div } \mathbf{D} = \rho$$

are frequently included as part of Maxwell's system, although they are not independent relations if one assumes the conservation of charge The last two are also known as the **Gauss law.** For linear homogeneous isotropic media, $\mathbf{B} = \mu\mathbf{H}$, $\mathbf{D} = \epsilon\mathbf{E}$. The values of μ and ϵ for a vacuum satisfy

$$\mu_v \epsilon_v = 1/c^2$$

where c is the speed of light.

MAXWELL M ∼ L BRIDGE. See **bridge, Maxwell M ∼ L.**

MAXWELL, CLERK, RELATION BETWEEN DIELECTRIC CONSTANT AND REFRACTIVE INDEX. According to Clerk Maxwell's identification of light with electromagnetic radiation, the dielectric constant ϵ and the refractive index, n, of a substance should be related by the formula $\epsilon = n^2$ This relation only holds under rather restrictive conditions, such as the absence of permanent dipoles in the substance, measurement with light of very long wavelength, etc

MAXWELL RELATIONS. Four thermodynamic relations which apply to the equilibrium state of a system, useful in evaluating the **thermodynamic functions.** In these relations p is the pressure, V, the volume, S, the entropy, and T, the absolute temperature.

(1) $$\left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial p}{\partial S}\right)_V$$

(2) $$\left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial p}{\partial T}\right)_V$$

(3) $$\left(\frac{\partial T}{\partial p}\right)_S = \left(\frac{\partial V}{\partial S}\right)_p$$

(4) $$\left(\frac{\partial S}{\partial p}\right)_T = -\left(\frac{\partial V}{\partial T}\right)_p$$

MAXWELL-WAGNER MECHANISM. A parallel-plate condenser made up of two parallel layers of material, one of dielectric constant ϵ, conductivity zero and thickness d, the other of finite conductivity σ and thickness qd can be shown to behave as if the

space between the plates were filled with a material of complex **dielectric constant**

$$\epsilon^* = \frac{\epsilon(1 + q)}{1 + (i\epsilon\omega q/4\pi\sigma)}$$

where ω is the frequency of the measuring field.

MAXWELL-WIEN BRIDGE. See **bridge, Maxwell-Wien.**

MAXWELLIAN FLUID. See **fluid, Maxwellian.**

MAXWELLIAN VIEW. A method of observing an **integrating photometric** sphere (i.e., a sphere with a white, diffusing inner wall, in which a light source is placed). In this method the source is focussed on the pupil of the eye; a method for weak sources

MAYDAY. The radio-telephone international distress call.

MAYER. A unit of **heat capacity** proposed by Richards. The mayer is the capacity of a body or system which is warmed 1 degree centigrade by 1 **joule.** The heat capacity of 1 gram of water at 20° is about 4.181 mayers.

MAYER THEORY OF CONDENSATION. The application of the Gibbs **phase integral** for a system of chemically-saturated molecules. Equations are derived for the thermodynamic properties of the system It is concluded that for a system consisting of liquid and its saturated vapor there are two characteristic temperatures T_m and T_c instead of one critical temperature. Below T_m the equations predict the usual condensation phenomena of a gas giving a condensed phase with a surface tension. Between T_m and T_c however, for a certain volume range the pressure P and the Gibbs **free energy** are independent of volume.

In Mayer's calculations on condensation and the **critical state,** the system is assumed to consist of independent **clusters** of molecules, each group or cluster consisting of one, two, three, etc., molecules.

MCW. (An abbreviation for "modulated continuous wave.") A form of emission in which the **carrier** is modulated by a constant audio-frequency tone. In telegraphic service, it is understood that the carrier is keyed.

MC LEOD GAUGE. A manometer used for determining low gas pressures by compressing a sample until its pressure reaches a measurable value.

MEACHAM BRIDGE OSCILLATOR. See **oscillator, Meacham bridge.**

MEAN ACTIVITY COEFFICIENT. See **mean activity of an electrolyte.**

MEAN ACTIVITY OF AN ELECTROLYTE. The logarithm of the mean **activity coefficient** of an electrolyte is the arithmetic mean of the logarithms of the individual ionic activity coefficients.

MEAN FREE PATH. (1) For sound waves in an enclosure, the average distance sound travels between successive **reflections** in the enclosure. (2) The average distance that a particle (e.g., a molecule) travels between successive collisions with the other particles of an **ensemble.** The computation of the magnitude of the mean free path depends upon the types of collisions postulated. If the particle moves at high velocity relative to the velocities of an ensemble of identical particles that have random positions, the relationship applies:

$$l = \frac{1}{n\sigma},$$

where l is the mean free path, n is the number of particles per unit volume, and σ is the effective cross-sectional area for collision. If, on the other hand, the velocities of the identical particles have a Maxwell distribution of velocities, the relationship applies:

$$l = \frac{1}{\sqrt{2}n\sigma}.$$

The mean free path may be extended to cover other particle-encounters than collisions, such as absorption, inelastic collision, etc., by using the relationship

$$l = \frac{1}{n\sigma},$$

where σ is the **cross-section** for the **process** under consideration.

MEAN FREE PATH, TRANSPORT. *A quantity which is equal to three times the* **diffusion coefficient,** in the case where the

medium through which the diffusion (of neutrons, for example) is taking place is a weak absorber.

MEAN FREE TIME. The average time between collisions. In solid state physics, an important example of the use of the term is to denote the average time between collisions of an electron with **impurities** in a **semiconductor.**

MEAN LIFE. See **life, mean.**

MEAN PULSE TIME. See **pulse time, mean.**

MEAN SQUARE DEVIATION. See **standard deviation.**

MEAN SQUARE VELOCITY (MOLECULAR). See **molecular velocity, mean-square.**

MEAN VALUE OF A FUNCTION. Defined for a function $f(x)$ over an interval (a,b) by

$$\frac{\int_a^b f(x)dx}{b-a}.$$

Over an area S it is defined by

$$\frac{\iint_S f(x,y)dS}{S}.$$

Over a region V of space it is defined by

$$\frac{\iiint_V f(x,y,z)dV}{V}.$$

MEAN VALUE THEOREM FOR A DERIVATIVE. Let $f(x)$ be a function which has a finite derivative at all points of the interval (a,b). Then there exists a value ξ of x between a and b such that

$$f(b) - f(a) = f'(\xi)(b - a).$$

MEAN VALUE THEOREM FOR INTEGRALS. The first law of the mean for integrals is:

$$\int_a^b f(x)dx = (b - a)f(\xi)$$

where $a \leqq \xi \leqq b$.

The second law of the mean for integrals may be written:

$$\int_a^b f(x)\phi(x)dx = \phi(a)\int_a^\xi f(x)dx$$

where $a \leqq \xi \leqq b$, provided $f(x)$ is continuous, and $\phi(x)$ is continuous and is also a positive monotonic decreasing function in the interval (a,b) and

$$\int_a^b f(x)\phi(x)dx$$

$$= \phi(a)\int_a^\xi f(x)dx + \phi(b)\int_\xi^b f(x)dx$$

where $a \leqq \xi \leqq b$ provided $f(x)$ and $\phi(x)$ are continuous functions and $\phi(x)$ is a monotonic decreasing function in the interval (a,b) without always being positive.

There are similar formulae for the case when $\phi(x)$ is an increasing function The two forms of the second theorem are known as the form of Bonnet and DuBois-Reymond, respectively

MEAN VELOCITY, MOLECULAR. See **molecular velocity, mean.**

MECHANICAL-ACOUSTICAL COUPLING. The interconnection of mechanical and acoustical elements. An example is provided by the production of acoustic vibrations in the air by the mechanical vibrations of a needle point.

MECHANICAL ADVANTAGE. See **Machines.**

MECHANICAL BANDSPREAD. A means of providing greater angular rotation of tuning control for a given tuning range by the use of a vernier dial or some similar mechanical device.

MECHANICAL COMPLIANCE. Compliance in a mechanical vibrating system is that coefficient which, when multiplied by 2π times the frequency, is the reciprocal of the negative imaginary part of the **mechanical impedance.** The unit is the centimeter per dyne.

MECHANICAL EQUIVALENT OF HEAT. It was in 1840 that James P. Joule began his classic researches on the quantitative relationship between **heat** and **work.** Rumford and Davy had established the fact that heat

is a form of energy; it remained to determine how many **foot-pounds** are equivalent to one **British thermal unit.** In the arrangement adopted by Joule, a heavy weight, in descending, was caused to drive a mechanism for "churning" water in a calorimeter. The energy furnished by the weight in its descent, with correction for friction losses, was then equated to the heat indicated by the rise in temperature of the agitated water, with the usual calorimeter corrections; the result indicated that 1 British thermal unit equals about 774 foot-pounds of energy. Translated into c.g.s. units, this meant that there are 41,600,000 ergs to the calorie; and when we consider that the most elaborately precise modern electrical methods give, as the present accepted value of "J," 4.1855×10^7 ergs per calorie or about 778 foot-pounds per British thermal unit, it is clear that Joule's experimental skill must have been of a high order

It has been customary, in writing thermodynamic equations involving both thermal and mechanical energy terms, to include the factor J in the former in order to reduce them to the same denomination; but the tendency at present is to express quantities of heat directly in ergs or joules, thereby avoiding the necessity of this factor (See **thermodynamics.**)

MECHANICAL EQUIVALENT OF LIGHT. The experimental problem in this determination is to separate the visible from the infrared and ultraviolet radiation One procedure is to enclose a lamp, of known power output, in a jacket which absorbs the invisible radiation and transmits the visible, the former being measured by the temperature-rise of the jacket and the latter photometrically. Measurements by Ives in 1926 with white light gave 1.6×10^{-3} watts per lumen. More recent measurements made at 555 mμ gave 1.46×10^{-3} watts per lumen, or 680 lumens per watt. (See also **luminosity function, standard.**)

MECHANICAL FILTER. A sharply-tuned **filter** consisting of appropriately-shaped metal rods which act as a series of coupled mechanical **resonators.** Electrical coupling into and out of the filter may be accomplished by **piezoelectric transducers.** Since successful operation of these filters may be achieved up to several hundred kilocycles, the filters find frequent application in the intermediate-frequency amplifiers of very selective superheterodyne receivers.

MECHANICAL IMPEDANCE. The complex quotient of the alternating force applied to a system by the resulting linear velocity in the direction of the force at its point of application The unit is the mechanical **ohm,** equivalent to 1 gm sec^{-1}.

MECHANICAL IMPEDANCE BRIDGE. Any device for measurement of a **mechanical impedance** by balancing methods.

MECHANICAL MASS. The part of the mass of a particle which is supposed to be an intrinsic property of the particle and not due to the interaction of the particle with itself through the medium of some field. The two types of masses are not experimentally distinguishable, however. (See **renormalization of mass.**)

MECHANICAL MOMENT OF INERTIA. Moment of inertia in a mechanical rotational system is that coefficient which, when multiplied by 2π times the frequency, gives the positive imaginary part of the **mechanical rotational impedance.** The unit is the gram-cm^2. (See also **inertia, momenta and products of.**)

MECHANICAL PASSIVITY. See **passivity, mechanical.**

MECHANICAL PHONOGRAPH RECORDER (MECHANICAL RECORDER). An equipment for transforming electric or acoustic signals into mechanical motion of approximately like form and inscribing such motion in an appropriate medium by cutting or embossing

MECHANICAL REACTANCE. The imaginary part of the mechanical impedance. The unit is the mechanical **ohm.**

MECHANICAL RECORD. A phonograph record.

MECHANICAL RECORDER. See **mechanical phonograph recorder.**

MECHANICAL RECTILINEAL IMPEDANCE. See **mechanical impedance.**

MECHANICAL RECTILINEAL REACTANCE. See **mechanical reactance.**

MECHANICAL RECTILINEAL RESISTANCE (MECHANICAL RESISTANCE). The real part of the **mechanical rectilineal impedance.** This is the part responsible for the dissipation of energy. The unit is the mechanical **ohm.**

MECHANICAL RECTILINEAL SYSTEM. A system adapted for the transmission of vibrations consisting of one or all of the following mechanical rectilineal elements: **mechanical rectilineal resistance, mass** and **compliance.**

MECHANICAL RESISTANCE. The real part of the mechanical impedance. The unit is the mechanical **ohm.**

MECHANICAL ROTATIONAL COMPLIANCE. In a mechanical rotational system, that coefficient which when multiplied by 2π times the frequency, is the reciprocal of the negative imaginary part of the **mechanical rotational impedance.** The unit is the radian per centimeter per dyne.

MECHANICAL ROTATIONAL IMPEDANCE (ROTATIONAL IMPEDANCE). The complex quotient of the alternating torque applied to the system by the resulting angular velocity in the direction of the torque at its point of application. The unit is the rotational **ohm.**

MECHANICAL ROTATIONAL REACTANCE (ROTATIONAL REACTANCE). The imaginary part of the **mechanical rotational impedance.** The unit is the rotational **ohm.**

MECHANICAL ROTATIONAL RESISTANCE (ROTATIONAL RESISTANCE). The real part of the **mechanical rotational impedance.** This is the part responsible for the dissipation of energy. The unit is the rotational **ohm.**

MECHANICAL ROTATIONAL SYSTEM. A system adapted for the transmission of rotational vibrations consisting of one or all of the following mechanical rotational elements; **mechanical rotational resistance, moment of inertia** and **rotational compliance.**

MECHANICAL SCANNING. See **television.**

MECHANICAL TELEVISION SYSTEM. See **television.**

MECHANICAL VIBRATING SYSTEM: CIRCULAR PLATES. The vibration of circular plates of uniform cross-section which are under no tension.

MECHANICAL VIBRATING SYSTEM: CLOSED PIPE. A vibrating column of fluid in a cylindrical pipe, open at one end, at which there must be a loop of displacement. The fundamental frequency of such a pipe, f, is given approximately by

$$f = c/4l,$$

where c = velocity of sound in cm/sec, l = length of pipe in cm, f = frequency in cycles/sec.

MECHANICAL VIBRATING SYSTEM: LONGITUDINAL VIBRATION OF BARS. The vibration of free rods in which the displacement of the particles is along the line of the bar.

MECHANICAL VIBRATING SYSTEM, OPEN PIPE. A vibrating column of fluid in a cylindrical pipe, open at both ends, at each of which there must be a loop of displacement The fundamental frequency f of such a pipe is given approximately by

$$f = c/2l,$$

where c = velocity of sound in cm/sec, l = length of pipe in cm, f = frequency in cycles/sec.

MECHANICAL VIBRATING SYSTEM: STRETCHED MEMBRANE. The vibration of a thin flexible membrane, stretched in all directions by a force which is not affected appreciably by the motion of the membrane.

MECHANICAL VIBRATING SYSTEM: STRING. A vibrating string, all parts of which vibrate in a plane perpendicular to the line of the string. The fundamental frequency of the string, f, in cycles per second, is given by

$$f = \frac{1}{2l}\sqrt{\frac{T}{m}}$$

where l = length of string in cm, T = tension in dynes, m = mass per unit length in gm/cm.

MECHANICAL VIBRATING SYSTEM: TORSIONAL VIBRATION OF BARS. The vibration of a solid tube or bar in which each

transverse section undergoes rotational vibration in its own plane.

MECHANICAL VIBRATING SYSTEM: TRANSVERSE VIBRATION OF BARS. The vibration of a bar, all parts of which vibrate in a plane perpendicular to the line of the bar. The fundamental frequency of vibration depends on the clamping position as well as on the length, density, type of cross-section and elastic constants of the bar.

MECHANICS. Mechanics is the branch of physics which deals with the effects of forces upon bodies at rest or in motion. The laws and phenomena of gases and liquids and solid bodies have a part in this subject, and it is one of the basic studies of engineering, physics and astronomy. It is customary to subdivide mechanics into the study of liquids (**hydraulics, hydrodynamics** and **hydrostatics**), the study of the action of gases (**pneumatics**), and the study of rigid or elastic particles or bodies of solid materials. It is to the latter field that the term mechanics is frequently restricted. For convenience it is further subdivided into **statics, kinematics,** and **kinetics.** Statics deals with bodies at rest, in equilibrium under the action of forces or of torques; kinematics deals with abstract motion and kinetics treats of the effect of forces or of torques upon the motions of material bodies. Modern usage favors the term **dynamics,** reserving mechanics for the more practical phases of the field (machinery, building, etc.).

Fluid mechanics is that branch of mechanics which deals with those fundamental laws which apply to all fluids (liquids or gases) at rest or in motion.

MEDIUM. A substratum in which a given system of physical entities exists or in which physical phenomena take place, as the transmission of force or energy. Physics deals with both material media (for example, fluids), and non-material media (for example, free space through which light may travel and which can be the locale of electromagnetic fields).

MEDIUM, INFINITELY DENSE. A medium that acts acoustically like a perfectly rigid wall.

MEDIUM, INFINITELY RARE. A medium that will not support any pressure changes.

MEDIUM, PRESSURE RELEASE. See **medium, infinitely rare.**

MEGA-. A prefix used with many physical units, denoting one million. Thus 1,000,000 volts = 1 megavolt. 10^6 cycles = 1 megacycle. (See **ultrasonics, microwaves.**)

MEGADYNE. One million dynes.

MEGA ELECTRON VOLT. One million electron-volts, a unit of energy.

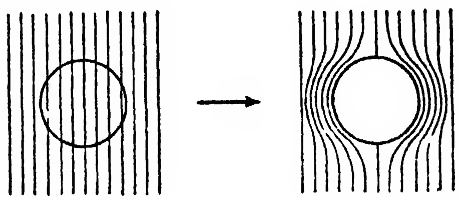
MEGAERG. One million ergs.

MEGAPHONE. An acoustical source, consisting of a voice source and a horn, usually either a conical horn or a thin parabolic horn.

MEGAPHONE, ELECTRICAL. A **megaphone** consisting of a combination of a **microphone, amplifier** and horn loudspeaker. (See **loudspeaker, horn.**)

MEGATRON. A name sometimes applied to disk-seal tubes, such as lighthouse tubes. (See **tube, lighthouse.**)

MEISSNER EFFECT. When a **superconductor** is cooled in a magnetic field the lines of induction are pushed out at the transition,



Meissner Effect (By permission from "Superfluids" by F London, Copyright 1950, John Wiley & Sons)

as if it exhibited perfect **diamagnetism,** an effect essentially distinct from the zero resistivity of the metal, which must be considered as a separate phenomenon.

MEISSNER, OSCILLATOR. See **oscillator, Meissner.**

MEL. A unit of **pitch.** By definition, a simple tone of frequency 1000 cycles per second, 40 decibels above a listener's **threshold,** produces a pitch of 1000 mels. The pitch of any sound that is judged by the listener to be n times that of a 1-mel tone is n mels.

MELLIN TRANSFORM. This **transform,** $f(y)$, and its inverse, $F(x)$, are defined, subject to certain conditions, by the relations

$$f(y) = \int_0^\infty x^{y-1}F(x)dx;$$

$$F(x) = \frac{1}{2\pi i}\int_{c-i\infty}^{c+i\infty} x^{-y}f(y)dy.$$

MELT. To fuse. To pass from the solid to the liquid state (see **fusion**). A "melt" is a fused mass.

MELTING CHANNEL. The restricted portion of the **charge** in a submerged-resistor or horizontal-ring **induction furnace** in which the induced currents are concentrated to effect high energy absorption and melting of the charge.

MELTING-POINT. The temperature at which the solid crystalline and liquid phases of a substance are in thermodynamic equilibrium. The melting-point, which depends to a small extent on the pressure, is well defined except for some glassy or resinous substances. The melting point is usually referred to normal pressure, 760 millimeters. The "melting point" of **liquid crystals** is the temperature at which the crystals lose their anisotropic properties.

MELTING POINT, CONGRUENT. The melting point of a compound at which the solid phase and the two-component liquid phase present have the same equilibrium composition.

MELTING POINT, INCONGRUENT. In the case of a two-component system which forms a compound that **dissociates** below its melting point, the temperature at which the solid form of that compound is in equilibrium with the two-component liquid and also with one of the solid components, or with the solid form of another compound formed from them

MEMBRANE POTENTIAL. See **Donnan equilibrium.**

MEMORY. Any device into which information can be introduced and then extracted at a later time The mechanism or medium in which the information is retained commonly forms an integral part of a **computer.**

MEMORY CAPACITY. The maximum number of distinguishable stable states in which a memory device can exist is a measure of its capacity. It is customary to use the logarithm to the base two of that number, as a numerical measure of the memory capacity is a binary digit.

MEMORY, SATURABLE CORE. See **magnetic memory.**

MENDELEVIUM. Transuranic element. Symbol Mv. Atomic number 101. Production, as nuclide of mass number 256, by bombardment of Element #99 with a beam of 41 mev α-particles from the 60-inch cyclotron at the University of California. This nuclide has a half-life between a half hour and several hours. It appears to decay by spontaneous fission.

MENISCUS. The curved surface of a liquid near the walls of its container The sense of the curvature depends on the angle of contact between the liquid surface and the material of the container, being concave upwards if the angle is less than a right angle and convex if it is greater.

MERCURY. Liquid metallic element. Symbol Hg (hydrargyrum). Atomic number 80.

MERCURY-198. One of the isotopes of mercury which has the desirable property of having extraordinarily-sharp spectral lines.

MERCURY ARC. The electric discharge through mercury vapor, between electrodes either of mercury or of some solid metal, is among the richest sources of **ultraviolet** radiation and has long been used as such. In the more common forms now in use at least one electrode is of mercury, deposited in a suitable reservoir at the end of a quartz tube. As these tubes are operated on moderate voltage, it is necessary to start or "strike" the arc by temporarily running a small stream of mercury through the tube from one electrode to the other. This makes a mercury conductor which quickly grows hot and fills the tube with mercury vapor, after which the mercury stream is broken and the arc is self-sustaining. The temperature is not nearly so high as in solid-electrode arcs, and these lamps are quite efficient. If the mercury vapor becomes too dense, the conductivity falls off; therefore in some forms, as the Cooper-Hewitt lamp, arrangements are provided for condensing the

vapor to a fixed density. The bulb must be made of quartz for ultra-violet because glass is highly opaque to that radiation. In some forms, a fluorite window is inserted, instead, in a glass bulb. Mercury arcs with glass tubes have proved useful to some extent for illumination and especially in photography, the light being a highly actinic blue-green.

The mercury-arc tube is used primarily as a power **rectifier** but occasionally has **grids** inserted and is used for power control purposes. Since the voltage drop across the tube is small and is constant the tube losses may be made relatively small by using fairly high circuit voltages. At a few hundred volts it is the most efficient converter for a-c to d-c transformation. In the larger power applications the tubes are operated on polyphase circuits, going even as high as 24 or more phases, with a common cathode and multiple anodes. This gives a d-c output which has very little ripple and hence needs little if any filtering.

MERCURY-HYDROGEN SPARK GAP CONVERTER. A spark gap generator or power source which utilizes the oscillatory discharge of a capacitor through an inductor and a spark gap as a source of radio-frequency power. The spark gap comprises a solid electrode and a pool of mercury in a hydrogen atmosphere.

MERCURY, PERIHELION OF. See **perihelion of Mercury, rotation of.**

MERCURY-VAPOR LAMP. See **lamp, mercury vapor.**

MERCURY WATTHOURMETER. See **watt hourmeter, mercury.**

MERIDIAN PLANE. Any plane of an optical system which contains the **optical axis.**

MERIDIANAL FOCUS. See **astigmatic focus.**

MERIT, GAIN-BANDWIDTH. See **gain-bandwidth.**

MERIT, SIGNAL-TO-NOISE. See **signal-to-noise.**

MEROMORPHIC. In complex variable theory, a function is meromorphic if it is **analytic** in a region of the complex plane except at **poles.**

MESH. A set of branches forming a closed path in a **network,** provided that if any one branch is omitted from the set, the remaining branches of the set do not form a closed path. The term loop is sometimes used in the sense of mesh.

MESH CONNECTION. A polyphase circuit connection in which the phase elements are connected end to end as opposed to the star connection where all phase elements have one end in common. The **delta connection** is the three-phase mesh connection and is by far the most common.

MESH IMPEDANCE (SELF-IMPEDANCE). The ratio of voltage to current in a **mesh,** all other meshes being opened.

MESNY CIRCUIT. A form of **push-pull,** ultra-high frequency **oscillator.**

MESIC ATOM. See **mesonic atom.**

MESOCOLLOID. A **colloid** composed of particles of relatively medium size, i.e., ranging from 0.025 to 0.25 micron.

MESODESMIC STRUCTURE. A type of **ionic crystal** in which one of the **cation-anion** bonds is equal in strength to all the bonds from the cation to the other anions. The silicates are important members of this class.

MESOMORPHIC STATE. Another term applied to those liquids which are doubly refracting (see **liquid crystal**). If the liquid is such that normal liquid flow does not occur, but rather the movement is one of gliding in one plane, then it is of the smectic type, e.g., *p*-azoxybenzoate. The nematic type, on the other hand, does not possess the layer structure of the smectic type, but resembles an **anisotropic liquid** in its ability to flow readily, and in its low viscosity. The nematic phases are optically uniaxial, and have a thread structure.

MESON. Any elementary particle having a rest mass intermediate between the mass of the electron and the mass of the proton. The following table lists representative mesons:

Name of Particle	Symbol	Mass in electron masses	Decay Scheme	Mean Life (in seconds)
Chi	$\chi^{\pm}$	1000–1500	$\pi^{\pm}$ + neutral particle	2×10^{-8}–2×10^{-9}
Kappa	$\kappa^{\pm}$	>1000	$\mu^{\pm} + 2\nu$	
Mu	$\mu^{\pm}$	210	$e^{\pm} + 2\nu$	2.1×10^{-6}
Pi	$\pi^{\pm}$	275	$\mu^{\pm} + \nu$	2.8×10^{-8}
Pi	π^{0}	265	$\gamma + \gamma$ $\gamma + e^{+} + e^{-}$	$10^{-15} - 10^{-14}$
Tau	$\tau^{\pm}$	975	$\pi^{\pm} + \pi^{+} + \pi^{-}$	About $\sim 10^{-9}$
Theta	θ^{0}	950	$\pi^{+} + \pi^{-}$	$>10^{-10}$

(In this table the charge of the particle is indicated by a superscript; ^{0} indicating neutrality, $^{\pm}$ indicating that particles of both signs are known, e^- indicating the electron, e^+, the positron, and ν, the neutrino.)

The International Cosmic-Ray Congress, on July 6–12, 1953, proposed the following classification for mesons and **hyperons:**

CLASSIFICATION OF PARTICLES

A. *Groups of Particles*

Light mesons (L-mesons):

π-mesons, μ-mesons, any other lighter meson which may be discovered.

Heavy mesons (K-mesons):

All particles heavier than π-mesons and lighter than protons.

Hyperons (Y-particles):

All particles with mass intermediate between that of the neutron and the deuteron (this definition might be revised if fundamental particles heavier than deuterons are discovered).

B. *"Christian Names"*

Use capital Greek letters for hyperons and small Greek letters for mesons.

(1) *Hyperons*

Λ^0: particle previously known as V_1^0 and characterized by the decay scheme $\Lambda^0 \rightarrow p + \pi^-$. If it turns out (as suggested by some results) that there are particles with this decay scheme and different Q-values, they could be designated by different subscripts.

Λ^+: the positive counterpart of Λ^0 with the possible decay schemes:

$$\Lambda^+ \rightarrow n + \pi^+$$

$$\Lambda^+ \rightarrow p + \pi^0$$

The existence of these particles is indicated by recent experiments.

(2) *Heavy Mesons*

$\tau \rightarrow 3\pi$ (considered certain).

$\kappa \rightarrow \mu + 2$ *neutral particles* (considered very probable, however, the nature of the neutral products is still unknown)

$\chi \rightarrow \pi + 1$ *neutral particle* (considered as probable; nature of neutral particle unknown).

θ^0: particle previously known as v^0, V_2^0, V_4^0, characterized by the decay scheme $\theta^0 \rightarrow \pi^{\pm} + (\pi^{\pm}$ or $\mu^{\mp})$. If it turns out (as suggested by some results) that there are particles with this decay scheme and several Q-values, they could be designated by different subscripts.

MESON FIELD THEORY. A theory of **nuclear forces** in which the meson field acts as the basis of the exchange between a proton and a neutron. The meson mass is intermediate between an electron and a proton. The **mesons** are regarded as the carriers of energy quanta in the meson field.

MESON FIELD THEORY (CHARGED MESON THEORY). **Meson field theory** which postulates the existence of positive and negative, but not neutral, **mesons.** The exchange between proton and neutron results from the transfer of a positive meson from the

former to the latter, or a negative meson in the opposite direction.

MESON FIELD THEORY (NEUTRAL MESON THEORY). Meson field theory which regards the proton and neutron as different energy states of the same fundamental particle, and the **meson,** which is responsible for the exchange interactions between them, is supposed to be electrically neutral.

MESON FIELD THEORY (SYMMETRICAL MESON THEORY). Meson field theory which combines the features of the neutral meson theory and the charged meson theory.

MESONS OR MESOTRONS, PRODUCTION OF. **Mesons** have been artificially produced by the interaction of light energy particles and photons with atomic nuclei; they have also been produced artificially by means of high-energy interactions between protons and protons, protons and neutrons, or by high energy photo-production.

MESON, MU. See **meson.**

MESON, PI. See **meson.**

MESON, RHO. A term that was used for a short time to designate a **meson** which stopped in a nuclear emulsion, but apparently without any concomitant decay event or nuclear interaction. Presumably most of these ρ-mesons actually were μ-mesons, the decay event being unobserved because of insufficient sensitivity of the emulsion.

MESON, SIGMA. A term that was used for a short time to designate a meson which produces a star. These mesons were soon identified as **π-mesons** (predominantly negative)

MESOTHORIUM (I AND II). Radioactive nuclides of the thorium family Mesothorium I has an atomic number of 88, and a half-life of 6.7 years. It emits β-rays and is an isotope of **radium.** Mesothorium II has an atomic number of 89, and a half-life of 6 13 hours. It emits β-rays and is an isotope of **actinium.** Mesothorium I is produced from thorium by α-ray emission. Mesothorium I yields Mesothorium II by β-ray emission, which, in turn, yields radiothorium by β-ray emission.

MESONIC ATOM. System consisting of an atomic nucleus and a negative π- or μ-meson held to it in a bound orbit mainly by electrostatic attraction. In general there will also be some electrons present in bound states, but because of the smaller electron mass their orbits will be well outside of those of the meson. Transitions from s-states of π-mesonic atoms are not observed, since for such states the life-time for capture by the nucleus is much less than the life-time for a radiative transitron. The energy-levels of a mesonic atom are approximately those of the corresponding ordinary atom, multiplied by the ratio of the meson mass to the electron mass.

MESOTRON. An obsolete synonym for **meson,** or for the μ-meson in particular.

METACENTER. A floating body is in equilibrium if the center of gravity and the center of buoyancy lie on a vertical line. If the body is displaced by a small angle from this position, the center of buoyancy will move, and the intersection of the vertical through the new center of buoyancy and the line joining the center of gravity and the equilibrium center of buoyancy is known as the metacenter The equilibrium is stable or unstable as the metacenter lies above or below the center of gravity.

METACENTRIC HEIGHT. The distance between the **metacenter** and the **center of gravity.**

METADYNE. A special, rotating-control generator more generally known as an **amplidyne.**

METAL. (1) Chemically, any element that can replace the hydrogen of an acid, i e., having the property of forming *cations.* (2) A member of the class of elements characterized by the bulk properties of "metallic" luster, high electric and thermal **conductivity, ductility** and **malleability.** The division of all the elements into metals and non-metals is not sharp; certain elements have a foot in both camps, e g , tin

The chemical properties are signs of the ability of the atom to lose one or more electrons to form a stable ion. In the solid state these electrons are not tightly bound to their separate atoms but can move nearly freely through the lattice, carrying electric and thermal currents (see **free electron theory of metals**). The plastic properties are explained by the *high* **coordination number of many**

metallic structures, a consequence of the undirected **metallic bonds**, which allow **dislocations** to move freely.

METAL DEPOSITION, DEPOLARIZATION OF. See **depolarization of metal deposition.**

METAL-TANK, MERCURY-ARC RECTIFIER. See **rectifier, metal-tank, mercury-arc.**

METALLIC BOND. See **bond, metallic** and **metal.**

METALLIC INSULATOR. A shorted section of transmission line or **waveguide** an odd number of quarter-wavelengths long The section offers a very high impedance to a waveguide, and may be employed as a mechanical support.

METALLIC REFLECTION. See **Fresnel equations for metallic reflection.**

METASTABLE NUCLEI. Nuclei in excited nuclear states that have measurable lifetimes (exceeding 10^{-10}–10^{-9} sec) (See **isomer, nuclear.**)

METASTABLE STATE. (1) A peculiar state of pseudo equilibrium, in which the system has acquired energy beyond that for its most stable state, yet has not been rendered unstable. Thus, by using great care, water at 760 mm pressure may be heated several degrees above its normal boiling point, say to 105°C, yet not boil. In this condition it has received heat energy beyond that normally required for liquid-vapor equilibrium, energy which it might be expected to release by spontaneously exploding into steam; and only a slight disturbance will precipitate that change, but the disturbance must come from some external source. (2) The term has been used in atomic physics for various **excited states,** but its most general usage today is for an excited state from which all possible **quantum transitions** to lower states are **forbidden transitions** by the appropriate **selection rules.**

METASTABLE SYSTEM. A system capable of undergoing a **quantum transition** to a state of lower energy, but having a relatively long **lifetime** in comparison with the most rapid quantum transitions of similar systems.

METASTASIC ELECTRON. An electron that moves from one atom to another, or from one shell to another in a given atom, or to the nucleus of the atom. **K-electron capture,** whereby the nucleus, usually in an induced radioactive reaction, captures an electron from the K-shell, is an instance of electron metastasis.

METASTASIS. A fundamental change in the position or orbit of a particle, as in the α-particle emission of certain radioactive nuclei. (See **metastasic electron.**)

METEOROGRAPH. A clock-operated instrument in which pens trace on a rotating drum a record of temperature, relative **humidity,** and pressure. The instrument is often used in the upper atmosphere, being carried aloft by a balloon, airplane, or kite. (See also **radiometeorograph.**)

METEOROLOGY. Science of the **atmosphere** including all its aspects. In a more restricted sense in wider use it is the science of weather, being particularly concerned with the physics of the elements which make the weather.

METER. (1) Any instrument or device used in a measurement. Often compounded with a prefix indicating the quantity measured, as in ammeter, voltmeter, potentiometer, etc (2) Unit of length in metric system. (See **meter, standard.**)

METER-CANDLE. A unit of **illuminance,** the same as the **lux.**

METER-CANDLE-SECOND. A unit of photographic exposure corresponding to an **illumination** of 1 **lux** acting for 1 second.

METER, MICHELSON METHOD OF MEASUREMENT OF. To count all of the 1,553,164.13 wavelengths of red cadmium light in the length of the standard meter would have been too great a task even for Michelson. He actually counted the wavelengths in a distance of 0.390625 mm, then, by comparing this with longer and longer distances, determined the actual length of the meter in reproducible wavelengths (See *Introduction to Optics, Geometrical and Physical*, Robertson.)

METER, STANDARD. The fundamental unit of the **metric system** is called the meter. The original standard meter bar, known as the *mètre des archives,* was constructed of platinum in 1793. Its length at 0°C was sup-

posedly one ten-millionth of the earth's meridian quadrant at sea level. This standard superseded an earlier provisional meter based on the length of a seconds pendulum. In 1875 the International Bureau of Weights and Measures was established at Sèvres, France, and one of its first tasks was the construction of a new standard for the meter. The result was the *international prototype meter,* a line standard made from an alloy of 90% platinum and 10% iridium. The meter is defined as the distance between two lines on the bar when at atmospheric pressure and 0°C. A supplementary definition of the meter can be given in terms of the wavelength of the red line of cadmium in air at 760 mm pressure and 0°C, according to which 1 m = 1,553,164.13 wavelengths. (This method was suggested by Professor Albert A. Michelson.) The ratio of the U.S. yard to the standard meter is exactly 3600/3937 by definition. A copy of the international prototype meter is kept at the National Bureau of Standards, Washington, D.C. It has recently been proposed that the wavelength of green radiation from the mercury isotope 198 (a much sharper and more intense line than the cadmium line just mentioned) replace the cadmium line as the ultimate standard of length. The proposed definition would make the international meter equal 1,831,249.21 wavelengths of the green line from mercury 198.

METHOD OF COMPONENTS. A trigonometrical procedure for adding forces in which the **components** of each force along a chosen set of orthogonal coordinate axes generally symbolized by x, y, and z are determined. The components along the x, y, and z axes are then added up separately to give the components of the resultant force. The magnitude and direction of the resultant force can then be determined from its components. These procedures can be used to add any vector quantities. (See **equilibrium; composition of forces.**)

METHOD OF MIXTURES FOR LATENT HEAT OF FUSION. A known amount of ice is dropped into a calorimeter containing a known amount of water at a given temperature. The water will cool, the final temperature being determined by the latent heat of fusion of ice and the specific heat of the molten ice. Since the latter is known, the former can be evaluated.

METRECHON. A form of **electrostatic storage tube.**

MEYER "HYDRAULIC" THEORY. A theory of hearing which maintains that the nature of the stimulation and the quality of the chemical process occurring in each of the sensitive cells of the **cochlea** determine the sensation quality or **pitch.**

MEV. Symbol for one million **electron volts,** a unit of energy.

M-F. Abbreviation for medium frequency.

MHO. A unit of **conductance,** the **reciprocal ohm.**

MICHELSON - MORLEY EXPERIMENT. Optical experiment, first performed with sufficient accuracy in 1887, to detect the motion of the earth through the ether. A monochromatic beam of light was divided by a half-silvered mirror and sent along two paths, later being brought together by further mirrors. According to the **ether hypothesis** the interference fringes so formed should have moved as the apparatus was rotated. The fact that such motion was not observed was an important basis for special relativity theory. (See **relativity theory, special.**)

MICHELSON ROTATING MIRROR (VELOCITY OF LIGHT). See **Foucault rotating mirror.** By placing the rotating mirror between the lens and the source and with the source at the exact focus of the lens, Michelson was able to so conserve light that his original distance was 700 meters. Later he used other rotating mirror arrangements. His final published value was 299,796 km/sec. New measurements in progress at the time of his death (1931) and published after his death by his collaborators gave 299,774 km/sec. Because of the difficulty of measuring the exact pressure and temperature in the long light-paths previously used, these last measurements were made in an evacuated pipe (tunnel) laid around a square, one mile on a side.

MICHELSON STELLAR INTERFEROMETER. An **interferometer** designed to be placed on a telescope, and used to **measure** the angular diameter of a star.

MICRO-. (1) A prefix used with many physical units, denoting one one-millionth. Thus,

1,000,000 microinches = 1 inch; 1,000,000 microvolts = 1 volt. (2) A prefix indicating smallness or extreme sensitivity, as in micrometer, microscope, microbalance.

MICROBALANCE. An apparatus used to weigh minute quantities of substances; consequently an extremely sensitive balance.

MICROBAR (DYNE PER SQUARE CENTIMETER). A unit of pressure commonly used in acoustics. One microbar is equal to 1 dyne per square centimeter. The term "bar" properly denotes a pressure of 10^6 dynes per square centimeter. Unfortunately, in acoustics the bar was used to mean 1 dyne per square centimeter. It is recommended, therefore, in respect to sound pressures that the less ambiguous terms "microbar" or "dyne per square centimeter" be used.

MICROCURIE. One-millionth **curie**; symbol μc.

MICRODENSITOMETER. A device usually applied in photographic spectroscopy to detect, by light-transmission measurements, spectrum lines recorded on a negative which are too diffuse or faint to be seen by the eye

MICROGRAM. One millionth of a **gram,** sometimes denoted by γ.

MICROLITER. One millionth of a **liter,** sometimes denoted by λ

MICROMETER. (1) The micrometer represents a general principle of **physical measurement,** used on various instruments such as **comparators, spherometers, compensators, interferometers,** etc. It is essentially a screw of accurately known, uniform pitch (commonly 1 mm or 0 5 mm), provided with a large head whose periphery is divided into equal parts, forming a scale. Turning the screw through a given number of these parts causes the shaft to travel through a distance which is a proportionate fraction of the pitch. For example, if the pitch is 0.5 mm and the head is divided into fiftieths, each scale division corresponds to a travel of 0.01 mm. A familiar application is the micrometer caliper, an instrument resembling an ordinary screw clamp. The screw is, however, of the micrometer design, with its scale reading zero when the caliper is closed. When unscrewed and closed again upon a thin plate or wire, the scale reading of the caliper shows the thickness of that object, in hundredths of a millimeter or thousandths of an inch. Measuring **microscopes** and astronomical **telescopes** are frequently equipped with a **filar micrometer.** (2) The term micrometer is sometimes used for the **micron,** one-millionth of a meter.

MICROMICRO-. Prefix denoting 10^{-12}. Thus 1 micromicrofarad ($\mu\mu f$) = 10^{-12} farad (f).

MICROMICRON. One millionth of a **micron,** or one trillionth of a meter, sometimes denoted by $\mu\mu$, one micromicron = 10^{-6} micron = 10^{-12} meter.

MICRON. Unit of length, abbreviation μ. Exactly 10^{-6} meter and 10^{-4} centimeter.

MICROPHONE. A device for converting sound waves into corresponding electrical variations.

MICROPHONE, ADP. A **microphone** in which a voltage is generated in a crystal of ammonium dihydrogen phosphate having converse piezoelectric properties.

MICROPHONE, ANTINOISE. A differential microphone (see **microphone, differential**) whose **signal-to-noise ratio** is improved by virtue of the cancellation of signals from distant (and supposedly noise) sources.

MICROPHONE, ASTATIC. A **microphone** with nondirectional characteristics.

MICROPHONE, BARIUM TITANATE. A **microphone** in which a voltage is generated in a barium titanate ceramic having converse piezoelectric properties.

MICROPHONE, BIDIRECTIONAL. A **microphone** in which the response predominates for sound incidences of 0° and 180°.

MICROPHONE, BOOM. A **microphone** which can be mounted upon a small, light boom.

MICROPHONE, CAPACITOR. A **microphone** which consists of a **capacitor** having a flexible diaphragm as one plate. A relatively-large, d-c polarizing voltage and a load **resistor** are connected in series with the capacitor. Sound-pressure variations cause the flexible diaphragm to move, resulting in changing currents through the load resistor.

MICROPHONE, CARBON. A **microphone** whose output current is function of the variable resistance created as carbon granules are alternately compressed and expanded by a diaphragm.

MICROPHONE, CARDIOID. A **microphone** consisting of a combination of a dynamic moving-coil type pressure element and an improved ribbon type velocity element enclosed in a housing which serves as a protective guard and also as a wind screen. When the outputs of these two elements are combined equally, the directional characteristic of the microphone is a cardioid curve.

MICROPHONE, CLOSE-TALKING. A **microphone** designed particularly for use close to the mouth of the speaker.

MICROPHONE, COMBINATION. A **microphone** consisting of a combination of two or more dissimilar microphones. Examples of combination microphones are: two oppositely-phased pressure microphones acting as a gradient microphone, and a pressure microphone and a velocity microphone acting as a unidirectional microphone.

MICROPHONE, CONDENSER. See **microphone, capacitor.**

MICROPHONE, CONTACT. A **microphone** designed to pick up mechanical vibrations directly without relying upon acoustic transfer.

MICROPHONE, CRYSTAL (PIEZOELECTRIC MICROPHONE). A **microphone** which depends for its operation on the generation of an electric charge by the deformation of a body (usually crystalline) having **piezoelectric** properties. (See **bimorph cell.**)

MICROPHONE, DIFFERENTIAL. A carbon-button **microphone** which has two buttons, one on either side of the diaphragm.

MICROPHONE, DIPOLE. A **microphone** in which the response is a function of the sound pressure between two distinct points.

MICROPHONE, DIRECTIONAL. A **microphone** the response of which varies significantly with the direction of sound incidence.

MICROPHONE, DIRECTIONAL CHARACTERISTIC OF. An expression of the variation of the behavior of a **microphone** with respect to direction. A polar diagram of the output variation of the microphone with direction is usually employed.

MICROPHONE, DYNAMIC. A **microphone** in which the sound-actuated diaphragm drives a coil positioned in a constant magnetic field, thus producing the desired induced voltage.

MICROPHONE, DYNAMIC INDUCTOR. A moving-coil **microphone** with a V-shaped diaphragm and a single straight conductor mounted along the bottom of the V. Sound waves cause the diaphragm to vibrate and the single conductor is moved in a magnetic field, thus generating an output voltage.

MICROPHONE, ELECTRICAL IMPEDANCE FREQUENCY CHARACTERISTIC OF. The **electrical impedance** at the output terminals of the **microphone** as a function of frequency.

MICROPHONE, ELECTRONIC. A **microphone** which depends for its operation on the generation of a voltage by the motion of one of the electrodes in an electron tube.

MICROPHONE, ELECTROSTATIC. See **microphone, capacitor.**

MICROPHONE, FIELD RESPONSE FREQUENCY CHARACTERISTIC. The ratio e/p as a function of frequency, where e is the open circuit voltage generated by the microphone, in volts, and p is the sound pressure, in dynes/cm^2, in a free progressive wave prior to the introduction of the microphone. (See **wave, free progressive.**)

MICROPHONE, GRADIENT. A **microphone** the output of which corresponds to a gradient of the sound pressure. Gradient microphones may be of any order as, for example, zero, first, second, and so forth. A pressure microphone is a gradient microphone of zero order. A velocity microphone is a gradient microphone of order one. Mathematically, from a directivity standpoint for plane waves the rms response is proportional to cos $n\theta$, where θ is the angle of incidence, and n is the order of the microphone.

MICROPHONES, HIGHER ORDER GRADIENT. Microphones in which the response corresponds to the order of the gradient of the sound pressure. The directional characteristics of gradient microphones are cosine func-

tions; the power of the cosine is the order of the gradient.

MICROPHONE, HOT-WIRE. A **microphone** which depends for its operation on the change in resistance of a hot wire produced by the cooling or heating effects of a sound wave.

MICROPHONE, HYDROSTATIC. A **microphone** containing an element which is sensitive to hydrostatic pressure. A barium titanate microphone is an example of this type.

MICROPHONE, LAPEL. A microphone adapted to positioning on the clothing of the user.

MICROPHONE, LINE. A directional microphone (see **microphone, directional**) consisting of a single straight-line element, or an array of contiguous or spaced electroacoustic transducing elements, disposed on a straight line, or the acoustic equivalent of such an array.

MICROPHONE, LIP. A **microphone** which is adapted for use in contact with the lip

MICROPHONE, MAGNETOSTRICTION. A **microphone** which depends for its operation on the generation of an electromotive force by the deformation of a material having magnetostrictive (see **magnetostriction**) properties.

MICROPHONE, MAGNETOSTRICTION SUBAQUEOUS. A **microphone** designed to operate under water in which a voltage is generated in a coil surrounding a rod having magnetostrictive properties. (See **magnetostriction.**)

MICROPHONE, MASK. A **microphone** designed for use inside an oxygen or other type of respiratory mask.

MICROPHONE, MOVING-COIL (DYNAMIC MICROPHONE). A moving-conductor microphone (see **microphone, moving conductor**) in which the movable conductor is in the form of a coil.

MICROPHONE, MOVING-CONDUCTOR. A **microphone** the electric output of which results from the motion of a conductor in a magnetic field.

MICROPHONE, NONLINEAR DISTORTION CHARACTERISTIC OF. A plot of the total distortion of a microphone, in per cent of the **fundamental,** as a function of the frequency.

MICROPHONE OMNIDIRECTIONAL (NONDIRECTIONAL MICROPHONE). A **microphone** the response of which is essentially independent of the direction of sound incidence. It should be noted that, in this case, omnidirectional refers to elevation as well as azimuth. In radio antenna practice this is not necessarily the case.

MICROPHONE, PARABOLIC. A **microphone** whose directional characteristics have been improved by a **parabolic reflector.**

MICROPHONE, PARABOLIC-REFLECTOR. A **microphone** employing a parabolic reflector to improve its directivity and sensitivity.

MICROPHONE, PHASE DISTORTION CHARACTERISTIC OF. A plot of the **phase angle** between the voltage output of the **microphone,** with respect to some reference voltage, as a function of the frequency

MICROPHONE, PHASE-SHIFT. A **microphone** employing phase-shift networks (see **network, phase shift**) to produce directional properties.

MICROPHONE, POLYDIRECTIONAL. A directional microphone (see **microphone, directional**) which can be adjusted to operate as nondirectional, bidirectional, etc.

MICROPHONE, PRESSURE. A **microphone** in which the electric output substantially corresponds to the instantaneous sound pressure of the impressed sound waves. A pressure microphone is a gradient microphone (see **microphone, gradient**) of zero order and is nondirectional when its dimensions are small compared to a wavelength. Various types of pressure microphone include the carbon, crystal and capacitor microphones.

MICROPHONE, PRESSURE-ACTUATED, RIBBON. A moving-coil microphone (see **microphone, moving-coil**) in which a light, corrugated metallic ribbon is suspended in a magnetic field. The ribbon is free to vibrate in response to sound waves.

MICROPHONE PRESSURE - RESPONSE FREQUENCY CHARACTERISTIC. The ratio e/p as a function of frequency, where e is the open-circuit voltage in volts generated by the microphone and p is the sound pressure upon the diaphragm of the microphone, in dynes/cm^2.

MICROPHONE, PUSH-PULL. A **microphone** which makes use of two like microphone elements actuated by the same sound waves and operating 180° out of phase.

MICROPHONE, QUARTZ-CRYSTAL, SUBAQUEOUS. A **microphone**, designed to operate under water, in which a voltage is generated in a quartz crystal having converse piezoelectric properties.

MICROPHONE, RIBBON. A moving-conductor microphone (see **microphone, moving-conductor**) in which the moving element consists of a thin, flat strip of metal, suspended in a magnetic field In addition to acting as a one-turn **moving coil**, the ribbon acts effectively as a **diaphragm**. The microphone has a very low impedance, is quite directional, and has generally good frequency-characteristics. It is often referred to as a velocity microphone (see **microphone, velocity**) since its output is inherently sensitive to the velocity, rather than the pressure of the impinging sound waves.

MICROPHONE, SINGLE-BUTTON CARBON. A carbon **microphone** which has a carbon granule resistance element on only one side of the diaphragm.

MICROPHONE, STANDARD. A **microphone** the response of which is accurately known for the condition under which it is to be used.

MICROPHONE, SUBAQUEOUS CONDENSER. A **microphone** which is designed to operate under water and which depends for its operation on variations in the electrical capacitance of a parallel-plate condenser.

MICROPHONE, THROAT. A **microphone** normally actuated by mechanical contact with the throat.

MICROPHONE, ULTRA-DIRECTIONAL. A **microphone** consisting of a number of separate lines, each covering a certain portion of the frequency range.

MICROPHONE, UNIDIRECTIONAL. A **microphone** with a substantially unidirectional pattern over the response range.

MICROPHONE, UNIDIRECTIONAL, COMBINATION TYPE. A unidirectional **microphone** consisting of a bidirectional microphone and a nondirectional microphone.

MICROPHONE, UNIDIRECTIONAL, SINGLE-ELEMENT TYPE. A unidirectional microphone consisting of a single element electroacoustic **transducer** with a phase-shifting network. (See **network, phase-shifting.**)

MICROPHONE, UNIDIRECTIONAL. UNIPHASE DYNAMIC TYPE. A unidirectional microphone employing a diaphragm-voice coil transducer unit and a phase shifting acoustical network to obtain unidirectional characteristics.

MICROPHONE, VARIABLE RELUCTANCE (MAGNETIC MICROPHONE). A **microphone** which depends for its operation on variations in the **reluctance** of a magnetic circuit.

MICROPHONE, VELOCITY. A **microphone** in which the electric output substantially corresponds to the instantaneous particle velocity (see **velocity, particle**) in the impressed sound wave. A velocity microphone is a gradient microphone (see **microphone, gradient**) of order one, and it is inherently bidirectional.

MICROPHONE, WAVE TYPE. A **microphone** which depends for directivity on wave interference.

MICROPHONIC NOISE. The high-pitched note which comes from the **speaker** of an **amplifier** or radio **receiver** when the set is subjected to a mechanical shock. It is caused by mechanical vibration of the vacuum-tube electrodes altering the electrical response of the **tube**. Hence any electrical disturbance resulting from mechanical disturbance of circuit elements.

MICROPHONISM (MICROPHONICS) (IN AN ELECTRON TUBE). The modulation of one or more of the electrode currents resulting from the mechanical vibration of a tube element.

MICROPHOTOGRAM. A greatly-enlarged photograph of a **spectrum,** or of a graphical record of a spectrum.

MICROPHOTOGRAPH. A very small photograph or one that has been greatly reduced in scale. (See **photomicrograph.**)

MICROPHOTOMETER. See **microdensitometer.**

MICRORADIOGRAPHY. The **radiography** of small objects where the detail is too fine to be seen by the unaided eye and the radiograph must either be examined with a low-power microscope or an enlargement must be made by projection. It is a relatively new field and one which is rapidly assuming considerable importance in the study of sections of tissue, leaf structure, insect anatomy, seeds, spray materials, textiles and artificial fibers and even the distribution of the constituents in an alloy. For this latter the material must be in the form of a thin section Soft, i e, low-voltage, x-rays are used and single-coated, fine-grain, high-resolution films or plates. The resulting radiograph may be enlarged from 10 to 100 times, depending on the subject, the film or plate, and the voltage used in exposing the radiograph.

MICRORECIPROCAL DEGREE. A convenient unit for the expression of reciprocal of the color temperature (see **temperature, color**). The value is expressed in microreciprocal degrees by the expression M.D. = 1,000,000/color temperature (°K).

MICROSCOPE. The optical instrument that bears this name consists essentially of two parts. (1) The objective is a lens combination, usually of small aperture and short focal length, which forms a real, inverted, and much enlarged image of the object at a point high up in the microscope tube, very much as a stereopticon objective throws an enlarged picture upon a distant screen. The objective-lens system is composed of several positive lenses, the first of which is hemispherical with its plane surface facing the object. Following this is a larger convexo-concave or "meniscus" lens, and then two still larger plano-convex achromati lenses (2) The **eyepiece** or ocular is placed eyond, with its focal plane coinciding with this image, and acts as a collimator, so that one looking into it sees a virtual image, subtending a wide angle. The instrument is focused by varying the distance between objective and object.

A **magnifier** is sometimes known as a simple microscope or a pocket microscope.

MICROSCOPE, COMPOUND. A microscope containing more than one lens or lens-system, commonly the lens-system in the objective and that in the eyepiece. This is the type of microscope in most general use.

MICROSCOPE, PHASE-CONTRAST. See **phase-contrast microscope.**

MICROSCOPE, POLARIZING. A microscope equipped with apparatus to examine objects under illumination by **polarized light.**

MICROSCOPE, ULTRAVIOLET. A microscope in which ultraviolet light is used to illuminate the object or field under examination. Some observing method, frequently photographic, must be used instead of the eye Because the resolving power of a microscope is inversely as the wavelength of the light used, an ultraviolet microscope may be used to resolve details too small to be seen with visible light For still higher resolution, an **electron microscope** is used.

MICROSCOPIC MOBILITY. The **mobility** of an untrapped particle in a **semiconductor.**

MICROSCOPIC REVERSIBILITY, PRINCIPLE OF. A postulate that each microscopic process occurring must be accompanied by an inverse process As stated in a specific case by Mitchell and Zemansky: "At equilibrium, the total number of molecules leaving a given quantum state in unit time shall equal the number arriving at that state in unit time, and also in unit time the number leaving by any one particular path shall be equal to the number arriving by the reverse path."

MICROSPECTROSCOPE. A combination **microscope** and **spectroscope.**

MICROSTRIP. A microwave transmission component utilizing a single conductor supported above a ground plane The configuration is equivalent to a **parallel-wire system,** for the image of the conductor in the ground plane produces the required symmetry. Losses are low, the component is extremely compact, and the cost is low since printed-circuit techniques may be employed for fabrication.

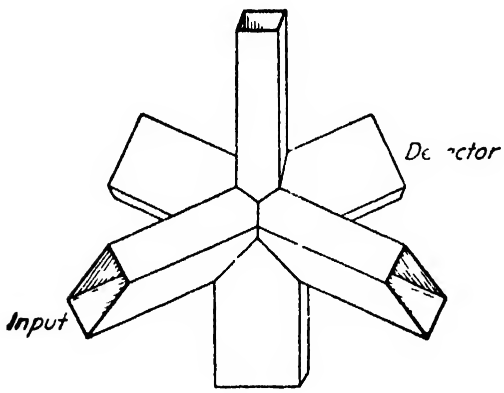
MICROVOLTS PER METER. The standard unit of signal strength or intensity of a **transmitter,** measured at some point. It is determined by dividing the receiving antenna voltage (microvolts) by the length (meters) of this antenna.

MICROWAVE. An electromagnetic wave having a wavelength in the **microwave region.**

MICROWAVE ABSORPTION IN PARAMAGNETIC SUBSTANCES. See **paramagnetic resonance.**

MICROWAVE ABSORPTION SPECTRA. The pure **rotation spectra** of many molecules lies in a frequency region which corresponds to a radiation wavelength in the millimeter range. By passing microwaves (millimeter wavelength range) through a gas, an absorption spectrum of the pure rotation frequencies of the gas molecules may be obtained.

MICROWAVE EQUIVALENT WHEATSTONE BRIDGE. A **waveguide** structure with six arms which may be used to measure the ratio of **admittances.** (See figure.)



Physical structure of microwave Wheatstone Bridge (By permission from "Microwave Theory and Techniques" by Reich et al, Copyright 1953, D Van Nostrand Co., Inc.)

MICROWAVE REGION. The portion of the electromagnetic spectrum lying between the far infrared and the conventional radiofrequency portion. While the microwave region is not bounded by definition, it is commonly regarded as extending from 300,000 megacycles to 1000 megacycles (1 mm to 30 cm in wavelength).

MICROWAVE SPECTROSCOPY. See **microwave absorption spectra.**

MIGRATION AREA (NUCLEAR REACTOR). The migration area of a medium is one-sixth the mean square distance that a neutron travels from its birth in fission until its absorption. The medium is assumed to be of infinite extent. In **Fermi age theory** of thermal reactors, the migration area is the sum of the age and the square of the thermal diffusion length. In multigroup theories of thermal reactors the migration area is the sum of the squares of the diffusion lengths for the various groups.

MIGRATION, ATOMIC. In its simplest form, the transfer of the valence bond of an atom from one atom to another within a molecule.

MIGRATION LENGTH. The square root of the **migration area.**

MIGRATION TUBE. A glass electrolytic apparatus used for investigation of **ionic migrations.** When it is filled with a solution containing ions and an indicator, and an electric current is passed, progress of the color change discloses the progress and rate of the migration of the ions.

MIKE. The abbreviation in common usage for **microphone.**

MILLER BRIDGE. A bridge for measuring the **amplification factor** of **vacuum tubes.**

MILLER CIRCUIT. A circuit which employs **negative feedback** from the output to the input of an **amplifier** through a **capacitor.**

MILLER EFFECT. The effect, due to **feedback,** which causes the input capacitance of a **vacuum-tube amplifier** to be larger than the sum of the static electrode capacitances. In some circuits a capacitor is deliberately placed between the **grid** and **plate** to provide a much larger magnitude of capacitance across the input terminals.

MILLER INDICES. According to the **Haüy law,** the intercepts of any crystal plane on the **crystal axes** may be expressed as rational fractional multiples of the **crystal parameters.** The Miller indices are the reciprocals of these fractions, reduced to integral proportions. Thus, the symbol (211) means the plane hav-

ing intercepts $\frac{1}{2}a$, b, c on the three axes respectively. The notation $\bar{2}$ is used to mean -2. In the hexagonal **crystal system,** four indices, the **Bravais-Miller indices,** are used.

MILLER INTEGRATOR. A **capacitor integrator** utilizing capacitance produced by the **Miller effect.**

MILLI-. A prefix used with many physical units, denoting one one-thousandth. Thus 1000 millimeters = 1 meter, 1000 milliamperes = 1 ampere.

MILLIBAR. The unit of pressure used in meteorology is the millibar, which is 1/1000 part of a **bar.** A bar is 1,000,000 dynes per sq cm. A millibar, therefore, is 1000 dynes per sq cm. "Bar" is often used by physicists and acoustic engineers to denote 1 dyne per sq cm. Also spelled barye.

MILLICURIE. One-thousandth of a **curie,** symbol mc.

MILLIGRAM. One-thousandth of a **gram.**

MILLIKAN METER. An **ionization chamber** of integrating type, especially useful for cosmic ray measurements. One of its features is a built-in **electroscope,** consisting of a gold-plated quartz fiber arrangement under torsion, which stands away from (is repelled by) its support when charged. The effect of the arrival of the charge to be measured is to neutralize partly the original charge and permit the fiber to approach its support.

MILLILAMBERT. A unit of **luminance,** equal to 1/1000 **lambert** or to 1/1000 π **candle**/sq cm.

MILLILITER. One-thousandth of a liter. One milliliter is 1.000028 cubic centimeters.

MILLIMASS UNIT. One-thousandth of an **atomic mass unit;** symbol mmu.

MILLIMETER. One-thousandth of a meter.

MILLIMICRON. A unit of length equal to 10^{-7} cm or 10^{-6} mm. Visible light has a wavelength of a few hundred (400–750) millimicrons. Frequently written mμ.

MILNE METHOD. A numerical procedure for solving a differential equation. If the given equation is $y' = f(x,y)$, four values each of y and y' are calculated by the method of Picard, expansion in the **Taylor series** or otherwise. The next value of y is predicted by integration of the **Newton interpolation formula** and corrected by the **Simpson rule** applied to the derivative. The process is repeated step-by-step as long as is necessary or desirable.

MILNE THEORY. See **kinematical relativity.**

MINIM. A unit of liquid measure, the sixtieth part of a fluid **dram.**

1 minim = 0.06161 milliliter.

MINIMAX. See **saddle point.**

MINIMUM. A point x_0 for a function $y = f(x)$ where the value of y is less than at any other point in the neighborhood of $x = x_0$ (see **maximum**). The test for a minimum is: $dy/dx = 0$ or ∞ at $x = x_0$; $dy/dx < 0$ for $x < x_0$; $dy/dx > 0$ for $x > x_0$; $d^2y/dx^2 > 0$.

MINIMUM BOILING POINT. A two-component or multi-component liquid system, in which a particular composition of the components has a lower boiling point than the pure components, or than any other composition of them, is said to have a minimum boiling point. It is the temperature at which boiling begins when the system is heated under conditions of stable equilibrium.

MINIMUM IONIZATION. See **ionization, minimum.**

MINIMUM PERCEPTIBLE DIFFERENCE (ACOUSTIC). The minimum difference in the frequency of two sounds that can be detected by the ear.

MINKOWSKI SPACE. A flat space of four dimensions of which three specify the position (x, y, z) of a point in space and the fourth dimension represents the time t at which an **event** occurs at that point. Usually the coordinates in the space are denoted by x_i $(i = 1, 2, 3, 4)$ with $x_1 = x$, $x_2 = y$, $x_3 = z$, $x_4 = ict$, where $i^2 = -1$. It is also possible to write $x_4 = ct$, but then it is necessary to associate with the space the **metric** g^{ij}, where $g^{11} = g^{22} = g^{33} = 1$, $g^{44} = -1$.

MINOR CYCLE. In a **digital computer** using serial transmission, the time required for the transmission of one word, including the space between words.

MINOR OF A DETERMINANT. A **determinant** of order $m < n$ obtained by deleting one or more rows and columns of a determinant of order n. If the row and column containing the element A_{ih} are removed, the resulting determinant is called the **complementary minor** to A_{ih}.

MINORITY CARRIER (IN A SEMICONDUCTOR). The type of **carrier** constituting less than half of the total number of carriers.

MINOR LOBE. See **lobe, minor.**

MINUTE. (1) Unit of time, abbreviation m or min. One 1440th part of a mean solar day; 60 seconds. (2) Unit of angle, abbreviation ′. One 60th part of a degree.

MIRAGE. A curious atmospheric phenomenon caused by the **total reflection** of light at a layer of rarefied air. The most familiar manifestation is observed in warm weather on paved highways. The air next to the pavement becomes heated and rarefied in comparison with that above it, so that at a sufficient angle of incidence, objects beyond the area are mirrored as if by polished silver, giving the almost irresistible impression that one is looking at a layer of water. Travelers in hot desert regions are sometimes thus deceived. Much more rarely the phenomenon appears in the air at a higher level than the observer. In either case the images are inverted; and because of the irregular contour of the air layer, they are usually distorted. A somewhat different effect, known as "looming," is produced by the refraction of light passing from rarefied air to a lower and denser layer. This results in distortion, making distant objects appear grotesquely elongated vertically, or in lifting into view objects beyond the horizon. It is most frequently observed at sea.

MIRROR NUCLIDES. Pairs of nuclides, having their numbers of protons and neutrons so related that each member of the pair would be transformed into the other by exchanging all neutrons for protons and vice versa.

MIRROR SIGN CONVENTION. See **sign convention.**

MISCH METAL. An alloy of cerium, lanthanum, and didymium sometimes sputtered on the cathodes of voltage-regulator **glow-tubes** to decrease the **cathode fall.** Arcs with a misch metal electrode are sometimes used to purify noble gases.

MISCIBILITY. The ability of two or more substances to mix, and to form a single, homogeneous phase.

MISCIBILITY GAP. The range of values in a given condition, usually temperature, under which liquids that are otherwise completely miscible mix only partially, or not at all.

MISCIBILITY, PARTIAL. In binary liquid systems A, B, it is possible to find liquids which are only partially miscible in each other. At a fixed temperature there is a concentration range over which two liquid layers are formed, one consisting of A saturated with B, the other of B saturated with A. When the two layers are in equilibrium they are termed conjugate solutions. Systems of this type are obtained with liquid pairs such as water and phenol, and aniline and hexane.

MITSCHERLICH, LAW OF. Substances that are similar in crystalline form and chemical nature usually have similar chemical formulas. Mitscherlich extended this conception by concluding that the crystalline form of compounds was determined only by the number and arrangement of their constituent atoms, but this is by no means a general law.

MIXED CRYSTALS. A homogeneous **solid solution** in which the crystal lattice sites are occupied, at random, by the molecules or ions of two different compounds. The property of forming a mixed crystal is typical of isomorphous substances, which must, however, also have similar atomic dimensions.

MIXED HIGH FREQUENCIES. The high-frequency portion of a color-television **video signal** which is the same for all color channels.

MIXED HIGHS. Those high-frequency components of the **picture signal** which are intended to be reproduced achromatically in a **color picture.**

"MIXER." (1) In a transmission recording, or reproducing system, a device having two or more inputs, usually adjustable, and a common output, which operates to combine linearly, in a desired proportion, the separate input signals to produce an output signal.

The term is sometimes applied to the operator of the above device. (2) In a **superheterodyne receiver** the first detector (or **transducer, heterodyne conversion**).

MIXER, CRYSTAL. A **heterodyne conversion transducer** employing a crystal rectifier as the modulating element.

MIXER TUBE. See **tube, mixer.**

MIXING. In isotope separation by gaseous diffusion through barriers, the process—diffusion, turbulent convection, or other—whereby the concentration gradient of the lighter isotope normal to the diffusion barrier is kept as small as possible.

MIXING EFFICIENCY. A measure of the effectiveness of the **mixing** process in terms of the effective simple process factor, and the factor which would obtain under conditions of perfect mixing.

MIXING-LENGTH THEORY (TURBULENT SHEAR FLOW). A theory of turbulent shear flow that assumes the effect of turbulent motion can be represented by supposing that small volumes of the fluid are transported a certain distance by the turbulent motion before mixing completely with their surroundings. During the period of transport, the small volumes carry with them unchanged the temperature or concentration (of another miscible fluid) appropriate to their place of origin. In the momentum transfer form of the theory, they also carry with them the initial momentum of the fluid volume, but the vorticity transfer theory assumes vorticity but not momentum conserved during the transport process.

MIXING, SYNCHRONOUS. A **product modulator** used as a **mixer** or **heterodyne conversion transducer.**

MKS SYSTEM. A system based directly upon the present-day metric fundamental standards, the **meter,** the **kilogram,** the mean solar **second;** whereas the c.g.s. system is based on the **centimeter, gram** and **second.** For example, the MKS unit of work or energy, the **joule,** is equal to 1 kg meter^2/sec^2 or 1 meter-newton, while the corresponding c.g.s. unit, the erg, is 1 gram cm^2/sec^2 or 1 centimeter-dyne.

MKSA UNITS. The practical (and absolute) electrical units based on the **meter, kilogram, second,** and **ampere** as fundamental units.

MMU. Symbol for millimass unit, one-thousandth of an **atomic mass unit.**

MOBILE EQUILIBRIUM, PRINCIPLE OF. Any change occurring in one of the conditions, such as temperature or pressure, under which a system is in **equilibrium,** causes the system to tend to adjust itself so as to overcome, as far as possible, the effect of that change.

MOBILE TRANSMITTER. See **transmitter, mobile.**

MOBILITY. (1) Random motion of various particles, such as sub-atomic particles, atoms, ions, molecules and colloidal particles. (2) Directed motion of charged particles subject to the action of forces and fields of force. Hence, the term mobility applies to all processes of electrical conduction, whether by ions, by electrons, by "holes," etc. The mobility, μ, is given by the expression

$$\mu = \frac{\sigma}{ne}$$

where σ is the conductivity, e is the charge of the carriers, and n is their number-density The mobility is, therefore, expressed in cm/sec per volt/cm, or in similar units, and it gives the drift velocity of the carriers under the influence of a unit electric field. In **semiconductors** the mobility may be directly determined from the **Hall effect,** and is related to the **mean free time** τ, between collisions by the formula

$$\mu = e\tau/m$$

and to the **Hall coefficient,** R_H, by the formula

$$\mu = R_H\sigma$$

where σ is the **conductivity.**

MOBILITY ANALOGY. An acoustical-mechanical dynamical analogy in which velocity corresponds to a voltage and force corresponds to a current. (See **mechanical impedance** and neighboring entries.)

MOBILITY, HALL (OF AN ELECTRICAL CONDUCTOR). The quantity μ in the relation

$$\mu = R_H\sigma$$

where μ is the Hall mobility, R_H is the Hall coefficient, and σ is the conductivity. (See **mobility; Hall effect.**)

MOBILITY, INTRINSIC. See **intrinsic mobility.**

MOBILITY, LIMITATION OF. The mobility of electrons in crystals is limited by two effects, scattering by thermal vibrations of the lattice (**intrinsic mobility**), and scattering by impurities. (See **Conwell-Weisskopf formula.**)

MOBILITY, MICROSCOPIC. See **microscopic mobility.**

MOBILITY OF IONS, EFFECTIVE. See **ions, effective mobility of.**

MOBILITY OF IONS IN SOLIDS. Conduction of electricity in **ionic crystals** is due to the motion of lattice **defects,** either of the **Schottky** or **Frenkel** type. The mobility is given by

$$\mu = (eD_0/kT)\epsilon^{-E/kT}$$

where D_0 is a numerical constant, and E is an **activation energy,** which depends on the energy required to make a defect and on the height of the energy barrier that must be surmounted in order that the defect may move.

MOBILITY, SEMICONDUCTOR. See **drift mobility.**

MÖBIUS STRIP. Take a strip of paper, give it a half-twist and paste the two ends together. The result is a *one-sided surface.*

MÖBIUS TRANSFORMATION. A general linear transformation in the complex plane Also called a **homographic transformation.**

MODE FILTER. A selective device designed to pass energy along a **waveguide** in one or more **modes** of propagation and substantially reduce energy carried by other modes.

MODE OF PROPAGATION (TRANSMISSION). A form of propagation of guided waves that is characterized by a particular field pattern in a plane transverse to the **direction of propagation,** which field pattern is independent of position along the axis of the waveguide. In the case of **uniconductor waveguides,** the field pattern of a particular mode of propagation is also independent of frequency.

MODE OF RESONANCE. A form of natural electromagnetic oscillation in a **resonator,** characterized by a particular field pattern which is invariant with time.

MODE TRANSDUCER (MODE TRANSFORMER). A device for transforming an electromagnetic wave from one **mode of propagation** to another.

MODERATING RATIO. In nuclear technology the ratio of the **slowing down power** to the macroscopic absorption cross section (see **cross section, macroscopic**). It is a measure of the effectiveness of a **moderator.**

MODERATION. Slowing down of a particle by collisions with nuclei. This term is applied especially to neutrons.

MODERATOR. A substance, such as graphite, used to slow down neutrons by means of **collisions.**

MODULATED AMPLIFIER. See **amplifier, modulated.**

MODULATED COLOR SUBCARRIER. See **carrier color signal.**

MODULATED WAVE. A wave, some characteristic of which varies in accordance with the value of a **modulating wave.**

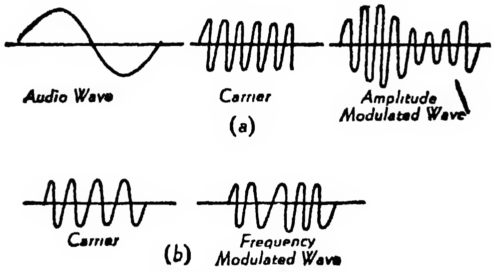
MODULATING ELECTRODE. An electrode to which a potential is applied to control the magnitude of the **beam current.**

MODULATING SIGNAL. The same as **modulating wave.**

MODULATING WAVE. A wave which causes a variation of some characteristic of the **carrier.**

MODULATION. The process or result of the process whereby some characteristic of one wave is varied in accordance with another wave. In radio communications, the modulated wave is called the **carrier,** and the other wave is called the **modulating wave.** By extension, the term modulation is applied to any process that varies a characteristic of the carrier. The **carrier** may be altered in accordance with the intelligence (speech, music, television picture signal, etc.) in three fundamental ways, by varying the amplitude of the carrier giving **amplitude modulation,**

by varying the frequency of the carrier giving frequency modulation, or by varying the phase of the carrier, thereby producing phase



Modulated waves

modulation. For definitions of these, and many related and derived types of modulation, see the following entries, and also those under **frequency modulation.**

MODULATION, ABSORPTION. A system for producing amplitude modulation (see **modulation, amplitude**) of the output of a radio transmitter by means of a variable-impedance device inserted in or coupled to the output circuit.

MODULATION, AMPLITUDE, OR AM. **Modulation** in which the **amplitude** of a wave is the characteristic subject to variation.

MODULATION, CONTROLLED - CARRIER. Amplitude modulation (see **modulation, amplitude**) systems in which the amplitude of the carrier is made to vary in accordance with the amplitude of the modulating signal (averaged over a short period of time).

MODULATION DETECTOR, AMPLITUDE. See **detector; demodulator.**

MODULATION, ANGLE. **Modulation** in which the angle of a sine-wave carrier is the characteristic subject to variation. **Phase** and **frequency modulation** are particular forms of angle modulation.

MODULATION CAPABILITY (AURAL TRANSMITTER). The maximum percentage **modulation** that can be obtained without exceeding a given **distortion figure.**

MODULATION, CATHODE. Amplitude modulation (see **modulation, amplitude**) accomplished by application of the modulating voltage to the cathode circuit.

MODULATION, CATHODE PULSE. **Modulation** produced in an **amplifier** or **oscillator** by application of externally generated pulses to the cathode circuit.

MODULATION, CONSTANT - CURRENT (HEISING). A system of amplitude modulation (see **modulation, amplitude**) wherein the output circuits of the signal amplifier and the carrier-wave generator or amplifier are directly and conductively coupled by means of a common inductor, which has ideally infinite impedance to the signal frequencies and which, therefore, maintains the common plate-supply current of the two devices constant. The signal-frequency voltage, thus appearing across the common inductor, appears also as modulation of the plate supply to the carrier generator or amplifier, with corresponding **modulation** of the carrier output.

MODULATION, CROSS. A type of **intermodulation** due to **modulation** of the **carrier** of the desired signal by an undesired signal.

MODULATION, DOUBLE. A **modulation** system in which the modulating signal is used to modulate a **sub-carrier.** The modulated sub-carrier is used in turn to modulate a **carrier.**

MODULATION, DOWNWARD. **Modulation** in which the instantaneous amplitude of the modulated wave is never greater than the amplitude of the unmodulated **carrier.**

MODULATION, DUAL. The **modulation** of a single carrier by two methods (such as **amplitude-** and **frequency-modulation**) simultaneously.

MODULATION, EFFECTIVE PERCENTAGE. For a single, sinusoidal input component, the ratio of the peak value of the fundamental component of the envelope to the direct-current component in the modulated condition, expressed in per cent. It is sometimes convenient to express percentage **modulation** in **decibels** below 100 per cent modulation.

MODULATION, ELECTRICAL. See **electrical modulation.**

MODULATION FACTOR. (1) The ratio of the peak variation actually used to the maximum design variation in a given type of **modulation.** In conventional amplitude modula-

tion the maximum design variation is considered that for which the instantaneous amplitude of the modulated wave reaches zero. (2) The modulation factor of an amplitude-modulated wave, has also been defined as the ratio of half the difference between the maximum and minimum amplitudes to the average amplitude. In linear modulation, the average amplitude of the envelope is equal to the amplitude of the unmodulated wave, provided there is no zero-frequency component in the modulating signal wave (as in telephony) For modulating signal waves having unequal positive and negative peaks, positive and negative modulation factors may be defined as the ratios of the maximum departures (positive and negative) of the envelope from its average value, to its average value

MODULATION, FREQUENCY. See **frequency modulation** for these entries

MODULATION, GRID. **Modulation** produced by the introduction of the modulating signal into the **control-grid** circuit of any tube in which the **carrier** is present.

MODULATION, GRID BIAS. See **modulation, grid.**

MODULATION, GRID PULSE. **Modulation** produced in an **amplifier** or **oscillator** by application of one or more **pulses** to a **grid circuit.**

MODULATION, HIGH-LEVEL. **Modulation** produced at a point in a system where the **power level** approximates that at the output of the system.

MODULATION, HUM. Modulation of a radio-frequency or detected signal by **hum.**

MODULATION INDEX. For a sinusoidal **modulating wave,** the ratio of the **frequency deviation** to the frequency of the modulating wave.

MODULATION, INTENSITY. Reproduction of an image by the variation of the light output of a **cathode-ray tube** in accordance with the signal.

MODULATION, LOSS. See **loss modulation.**

MODULATION, LOW-LEVEL. **Modulation** produced at a point in a system where the power level is low compared with the power level at the output of the system.

MODULATION MEASUREMENT BY COMPONENT METHOD. A method which requires the linear rectification or detection of an amplitude-modulated **carrier.** After filtering, the d-c value of output is proportional to the carrier, and the a-c value of the output is proportional to the modulation. The ratio of the a-c to the d-c values, multiplied by 100 is thus the percentage modulation.

MODULATION MEASUREMENT BY DOUBLE-RECTIFIER METHOD. A method of measuring peak amplitude modulation employing a **diode detector.** The average value of the pulsating d-c output is proportional to the **carrier,** the highest values of the d-c are caused by positive modulation peaks, and the lowest voltages result from the negative modulation peaks.

$$\text{Positive Modulation } \% = 100(V_p - V_c)/V_c$$

$$\text{Negative Modulation } \% = 100(V_c - V_n)/V_c$$

$$\text{Modulation } \% = 100(V_p - V_n)/2V_c$$

where V_c is the average value of d-c output, V_p is the maximum value of d-c output, and V_n is the minimum value of d-c output.

MODULATION, MULTIPLE. A succession of processes of **modulation** in which the **modulated wave** from one process becomes the **modulating wave** for the next In designating multiple-modulation systems by their letter symbols, the processes are listed in the order in which the signal intelligence encounters them For example, PPM-AM means a system in which one or more signals are used to position-modulate their respective pulse subcarriers which are spaced in time and are used to amplitude-modulate a carrier.

MODULATION, NEGATIVE. In an amplitude-modulation television system, that **form** of **modulation** in which an increase in **brightness** corresponds to a decrease in transmitted power.

MODULATION, NEGATIVE PICTURE. In television, a method of transmitting the television video signal so that all the picture values are reversed. The brightest portions of the image are represented by the least amount of voltage, while the dark sections of the image have large voltage (or current) values.

MODULATION NOISE. See **noise, modulation.**

MODULATION, PERCENTAGE. The **modulation factor** expressed as a percentage.

MODULATION, PHASE (PM). Angle modulation (see **modulation, angle**) in which the angle of a sine-wave carrier is caused to depart from the carrier angle by an amount proportional to the instantaneous value of the **modulating wave.** Combinations of phase and frequency modulation are commonly referred to as "frequency modulation."

MODULATION, PLATE (ANODE). Modulation produced by introducing the **modulating signal** into the plate circuit of any tube in which the **carrier** is present.

MODULATION, POSITIVE. In an amplitude-modulation television system, that form of **modulation** in which an increase in **brightness** corresponds to an increase in transmitted power.

MODULATION, PULSE. (1) Modulation of a carrier by a pulse train. In this sense, the term is used to describe the process of generating carrier-frequency pulses. (2) Modulation of one or more characteristics of a pulse carrier. In this sense, the term is used to describe methods of transmitting information on a pulse carrier. (See **quantized pulse modulation.**)

MODULATION, PULSE-AMPLITUDE OR PAM. **Modulation** in which the **modulating wave** is caused to amplitude-modulate a **pulse carrier.**

MODULATION, PULSE-CODE (PCM). Modulation which involves a **pulse code.** This is a generic term, and additional specification is required for a specific purpose

MODULATION, PULSE-DURATION OR PDM. Pulse-time modulation in which the value of each instantaneous sample of the modulating wave is caused to modulate the duration of a pulse. The terms "pulse-width modulation" and "pulse-length modulation" also have been used to designate this system of modulation. In pulse-duration modulation, the **modulating wave** may vary the time of occurrence of the leading edge, the trailing edge, or both edges of the pulse.

MODULATION, PULSE FREQUENCY (PFM). A form of pulse time modulation (see **modulation, pulse time**) in which the pulse repetition rate is the characteristic varied. A more precise term for "pulse frequency modulation" would be "pulse repetition-rate modulation."

MODULATION, PULSE-POSITION OR PPM. Pulse-time modulation (see **modulation pulse-time**) in which the value of each instantaneous sample of a **modulating wave** is caused to modulate the position in time of a **pulse.**

MODULATION, PULSE-TIME OR PTM. **Modulation** in which the values of instantaneous samples of the **modulating wave** are caused to modulate the time of occurrence of some characteristic of a **pulse carrier.** Pulse-duration modulation and pulse-position modulation are particular forms of pulse-time modulation.

MODULATION, REACTANCE. **Modulation** produced by a variable reactance. Reactance modulation may be achieved in the following ways: Electronically by the use of a **reactance tube;** mechanically by varying the capacitor plate-spacing or position with a motor or other device; electrically by varying the effective inductance of an iron-core inductor by superimposing a d-c **magnetomotive force;** or electrically by superimposing a d-c electrostatic field on a capacitor, whose dielectric constant varies as a function of electrostatic field strength.

MODULATION, SCREEN-GRID. **Modulation** produced by introduction of the **modulating signal** into the screen-grid circuit of any multigrid tube in which the **carrier** is present.

MODULATION, SELF-PULSE. **Modulation** effected by means of an internally generated **pulse.** For example, see **"blocking oscillator."**

MODULATION, SERIES. Plate modulation of a class-C amplifier (see **amplifier, class-C**) stage by the insertion of a modulator tube directly in the anode or cathode lead of the stage. Since the use of a modulation choke or transformer is not required, the circuit is capable of uniform frequency response over a wide frequency-band.

MODULATION, SINGLE-SIDEBAND OR SS. **Modulation** whereby the **spectrum** of the **modulating wave** is translated in frequency by a specified amount either with or without **inversion.**

MODULATION, SPARK-GAP. A **modulation** process which produces one or more **pulses** of energy, by means of a controlled spark-gap breakdown, for application to the element in which modulation takes place

MODULATION, SUPPRESSOR GRID. **Modulation** produced by introducing the modulating signal into the **suppressor grid** of a **pentode,** in which the **carrier** is also present.

MODULATION, TIME. See **time modulation.**

MODULATION, VELOCITY. A form of electron **modulation** in which the electrons passing through a resonant cavity in a tube such as the **klystron** are acted upon by a modulating field in such a manner that their velocities cause them to pass through the collector cavity in groups.

MODULATION, VESTIGIAL SIDEBAND. An amplitude-modulation (see **modulation, amplitude**) system which transmits one sideband and a portion of the other sideband which lies adjacent to the **carrier frequency.** This is the modulation system employed by the video portion of television transmitters, as a bandwidth-conservation measure.

MODULATOR. A device to effect the process of **modulation.**

MODULATOR, BALANCED. A **modulator,** specifically a push-pull circuit, in which the **carrier** and **modulating signal** are so introduced that, after modulation takes place, the output contains the two **sidebands** without the carrier.

MODULATOR, CLASS-A. A class-A amplifier (see **amplifier, class-A**) which is used specifically for the purpose of supplying the necessary signal power to **modulate** a **carrier.**

MODULATOR, CLASS-B. A class-B amplifier (see **amplifier, class-B**) which is used specifically for the purpose of supplying the necessary signal power to **modulate** a **carrier.**

MODULATOR, COPPER-OXIDE. A rectifier modulator (see **modulator, rectifier**), having copper-oxide rectifier elements. Widely used because of permanence of characteristics.

MODULATOR, FREQUENCY. A device for producing **frequency modulation.** (See **reactance tube.**)

MODULATOR, MAGNETIC. See **magnetic amplifier.**

MODULATOR, PRODUCT. A **modulator** whose output is proportional to the product of the **carrier** and the **modulating signal.** The desired result can be achieved by sampling the modulating wave briefly at regular intervals at the carrier rate, and applying the ensemble of samples to the input of a band-pass filter having a **center frequency** coincident with the carrier frequency. One fundamental property of a product modulator is that the carrier is normally suppressed.

MODULATOR, PULSE. A device which applies **pulses** to the element in which **modulation** takes place.

MODULATOR, REACTANCE. A device, used for the purpose of **modulation,** whose reactance may be varied in accordance with the instantaneous amplitude of the modulating electromotive force applied thereto. This is normally an electron-tube circuit and is commonly used to effect phase or frequency modulation (See **modulation, phase or modulation, frequency.**)

MODULATOR, RECTIFIER. A modulator employing a **diode** or diodes. The carrier source, modulating source, diode, and load are conventionally connected in series. Because of inherently low efficiency, this method is employed only at small signal levels

MODULATOR, SQUARE LAW. A device whose output is proportional to the square of its input. The **carrier** and **modulating signal** are added in the input to produce a modulated carrier in the output.

MODULI OF ELASTICITY. See **modulus of elasticity.**

MODULUS. (1) The **absolute value** of a **complex number.** It may be interpreted as the length of a vector representing the number in complex space Thus the modulus of $(a + ib)$ is $(a^2 + b^2)^{1/2}$, or if the number is given in the form $r(\cos \phi + i \sin \phi)$ or $re^{i\phi}$, its modulus is r.

(2) The modulus of common logarithms is $\log e = 0.434294\cdots$, the factor which converts a natural logarithm to a common logarithm. Similarly the modulus of natural logarithms is $\ln 10 = 2.302585\cdots$.

(3) A parameter which occurs in **elliptic functions** or **integrals.**

(4) A formula, coefficient, or constant that expresses a measure of a property, force, or quality, such as elasticity, efficiency, density, or strength.

MODULUS OF ELASTICITY. The ratio of the unit **stress** to the unit **deformation** of a structural elastic material is a constant, as long as the unit stress is below the **proportional limit,** and is called the modulus of elasticity. The shearing modulus of elasticity is frequently called the modulus of rigidity. (See **proportional limit, tension test, Hooke law.**)

MODULUS OF RESILIENCE. See **resilience.**

MODULUS OF RIGIDITY. See **shear modulus.**

MOIRE. In television, the spurious pattern in the reproduced picture resulting from interference beats between two sets of periodic structures in the image Moires may be produced, for example, by interference between regular patterns in the original subject and the target grid in an **image orthicon,** between patterns in the subject and the line pattern and the pattern of phosphor dots of a three-color kinescope, and between any of these patterns and the pattern produced by the **carrier color signal.**

MOLAL. Pertaining to moles, as that term is used in chemistry to refer to **gram-molecular weights,** which are the molecular weights of substances expressed in grams; or as of a solution, containing one gram-molecular weight of solute per kilogram of solvent.

MOLAL CONCENTRATION. The number of **moles** (gram-molecules) of a substance per unit mass of a phase or a system. For example, a molal solution contains one gram-molecular weight of solute dissolved in one kilogram of solvent.

MOLAL VOLUME. The volume occupied by one **mole** of a substance in a specified state under specified conditions. The molal volume of gas, under **standard conditions,** is approximately 22.4 liters.

MOLALITY. The number of **moles** (gram-molecules) of a substance per unit mass of a phase or system, as of solute per kilogram of solvent.

MOLAR. Pertaining to molecules, or to moles per unit volume; thus a molar solution is one containing one gram-molecular weight of solute per liter of solution.

MOLAR ABSORPTION COEFFICIENT. See **Beer law.**

MOLAR CONCENTRATION. The number of moles (gram-molecules) of a substance per unit volume of a system. For example, a molar solution contains one mole of solute per liter of solution.

MOLAR CONDUCTANCE. See **conductance, molar.**

MOLAR EXTINCTION COEFFICIENT. See **Beer law.**

MOLAR (HEAT CAPACITY, VOLUME, POLARIZATION, . . . ETC.). The heat capacity, volume, polarization, . . etc , of one **gram molecular weight** or mole of a substance. Since a mole contains always the same number of molecules, whatever the substance, molar quantities usually occur in laws connecting atomic and macroscopic phenomena in rather simpler ways than do quantities expressed "per unit mass," or "per unit volume." (See, for example, **Dulong and Petit law.**)

MOLAR LATENT HEAT OF VAPORIZATION. The quantity of heat required to convert one **mole** of a substance into vapor at its boiling point under atmospheric pressure.

MOLAR QUANTITY, APPARENT. See **apparent molar quantity.**

MOLAR SURFACE. The surface of a sphere the mass of which is one **mole.**

MOLAR SURFACE-ENERGY. The energy necessary to form a sphere (gravitational influences removed) from a mass of any liquid equal to one **mole.** At the critical point the molar surface energy is zero. It decreases proportionately to increase of temperature, and its temperature coefficient is the same for all homogeneous liquids.

MOLAR VOLUME. The volume occupied by a **mole** of any substance in vapor (reduced to 0°C and 760 mm). For gases it is approximately equal to 22.4 liters.

MOLE (MOL). One gram-molecule of any substance, i.e., the molecular weight of the substance expressed in grams; thus a mole of sulfuric acid weighs 98.08 grams.

MOLE FRACTION. The fraction n_i/n, that is, the ratio of the number of **moles** (or molecules) of any constituent of a homogeneous mixture to the total number of moles (or molecules).

$$N_i = \frac{n_i}{n_1 + n_2 + \cdots n_i + \cdots} = \frac{n_i}{n}$$

where N_i is the mole fraction of constituent i, n_i is the number of moles of constituent i, and n is the total number of moles of all the constituents of the mixture

MOLECULAR. Pertaining to, or characteristic of, molecules.

MOLECULAR ATTRACTION. Force of attraction between molecules which plays an important role in many phenomena, e g , in causing departure of behavior of real gases from ideality. Molecular attractive forces are thought of in terms of three contributions, all electrostatic. (1) The orientation effect (Keesom) applies to molecules possessing a permanent **dipole moment.** Interaction between the rotating dipoles gives net attractive force between two molecules

$$F_0 \propto \frac{1}{r^7} \cdot \frac{1}{T},$$

where r is the separation, T the absolute temperature. This cannot account for entire cohesive force, because the latter varies much less rapidly with temperature, and because many molecules do not possess permanent dipoles. (2) Induction effect (Debye). Since dipoles are not rigid, each is affected by the field of the others, giving effectively additional induced dipole. Interaction between induced and inducing dipoles gives attractive force

$$F_I \propto \frac{1}{r^7},$$

independent of temperature. For non-polar molecules, existence of "quadrupole moments" is assumed, which can induce a dipole in other molecules. Quadrupole-dipole interaction gives force

$$F_q \propto \frac{1}{r^9},$$

which is negligible except at short distances. (3) London dispersion effect, so called because of its connection with optical dispersion. Molecules which have no *average* dipole moment, still possess an instantaneous dipole moment which averages out in time. Interaction between these and other induced instantaneous dipoles gives force

$$F_D \propto \frac{1}{r^7}.$$

In addition, there are fluctuating quadrupoles which induce fluctuating dipoles, giving force

$$F_Q \propto \frac{1}{r^9}.$$

The relative importance of all these effects depends on the type of molecule.

MOLECULAR BEAM. A unidirectional stream of neutral molecules passing through a vacuum, generally with thermal velocity. Such a beam may be produced by emergence from a pinhole in a chamber containing low pressure gas or vapor, and it may be defined by a system of slits. By passing the beam through known electric or magnetic fields, quantities such as nuclear magnetic moments can be determined. (See **molecular ray; mass spectrograph.**)

MOLECULAR BEAM RESONANCE METHOD FOR NUCLEAR MAGNETIC MOMENTS. See **Rabi method.**

MOLECULAR COLLISION. Collision between molecules, which may be perfectly elastic (e g., gas in thermodynamic equilibrium), or inelastic, resulting in chemical reaction, radiation, etc. The pressure of a gas is attributed to collision of the molecules with the walls of the container.

MOLECULAR CRYSTAL. See **crystal, molecular.**

MOLECULAR DIAGRAM. A drawing to scale which shows certain of the structural properties of a molecule, and the constituent

atoms, including the **bonds** between the atoms, the **effective radii**, the **ionic radii**, and, in general, the shape of the molecule.

MOLECULAR DIAMETER. Values for the molecular diameter have been obtained by calculation, using the equations for the **mean free path**, for **diffusion**, for **polarization**, for **viscosity**, for **thermal conductivity**, and for **specific heat**. Values for the molecular diameter of the same gas computed by more than one of these methods often agree closely, but it is not a precise quantity, except that it measures the general extent of the electronic cloud about the molecule.

MOLECULAR DISTILLATION. An isotope separation process in which molecules are evaporated from a surface at extremely low pressures and are condensed before undergoing collisions.

MOLECULAR EXCITATION. The process of putting an atom or a molecule into a condition in which the total energy of its interior mechanism is greater than it is in the normal or "ground" state. (This does not refer to energy of translational motion of the particle as a whole.) According to the **quantum theory**, the energy required to accomplish such a change must be supplied in certain definite amounts or quanta. An amount different from an "excitation limit" can not be received by the atom or molecule. The necessary energy may be supplied by a **collision** with another atom or with an electron (as a cathode particle), or by the advent of a radiation quantum. In the former case the impinging atom or electron must have at least a certain speed (see **critical potential**); in the latter, the frequency of the radiation must be sufficient to give its quanta the necessary energy. (See **Planck law.**)

MOLECULAR FIELD APPROXIMATION. A simple and often reasonably accurate method for treating problems of **ferromagnetism, antiferromagnetism**, etc. Each magnetic ion is treated independently as if in a field consisting of any external field, H together with the field H' created by the net polarization of its neighbors. H', in its turn, gives the ion an average polarization, which must be put equal to that assumed for any equivalent neighbors. This self-consistency condition is sufficient to give the polarization as a function of temperature. The assumed field H' may not be just a magnetic field, but the equivalent effect of other processes, such as the **exchange interaction** between the spins. The method is equivalent to the **Bragg-Williams** treatment of **order-disorder** phenomena.

MOLECULAR FLOW. The relative rate of flow of gas molecules through a fine **orifice**, a function of the gas pressure and density, and the size and character of the orifice.

MOLECULAR FREE PATH. The average free path or distance traveled by a molecule between collisions in a gas or in a solution.

MOLECULAR MODEL. A scale model, made of wires, varicolored balls, or other devices, which shows certain of the structural features of a molecule and its constituent atoms—their grouping, relative positions, etc.

MOLECULAR NUMBER. (1) The sum of the **atomic numbers** of the atoms in a molecule. (2) An integral number denoting the position occupied by a given molecule in a series obtained by arranging molecules in order of increasing molecular frequency.

MOLECULAR ORBITAL. The **wave function** of an electron moving in the field of the other electrons and nuclei composing a molecule. (See **orbital.**)

MOLECULAR ORIENTATION IN SURFACE. The nature of the packing of the surface layer of molecules. For example, a condensed film of a long-chain fatty acid on water is arranged in such a way that the general direction of the chains is probably upright. In the corresponding gaseous film, the molecules may lie flat on the surface. In the case of a polar aliphatic liquid, the molecules of the surface layer orient themselves with their non-polar hydrocarbon chains towards the air, and the polar ends pointing in the direction of the liquid.

MOLECULAR PUMP. See **diffusion pump.**

MOLECULAR RAY. See **molecular beam.**

MOLECULAR ROTATION. The product of the **specific rotation** and the molecular weight, divided by 100.

MOLECULAR SOLUTION. A solution in which the **solute** is present in aggregates not containing more or less than one molecule of

solute; in other words, a solution in which there are no associated molecules or ions.

MOLECULAR SOLUTION VOLUME. The difference in volume between one liter of pure **solvent** and a solution that contains one mole of dissolved substance per liter.

MOLECULAR SPECTRUM. See **spectrum, molecular.**

MOLECULAR VELOCITY. In general, the velocity of a molecule due to random thermal motion, i.e., the quantity c appearing in the **Maxwell-Boltzmann distribution law.**

MOLECULAR VELOCITY, MEAN. If an assembly of particles contains a number n_1 moving with velocity c_1, n_2 moving with velocity c_2 $\cdots$, the mean velocity $\bar{c}$ is defined as

$$\bar{c} = \frac{n_1c_1 + n_2c_2 + \cdots}{n_1 + n_2 + \cdots}.$$

Strictly speaking, the mean molecular **velocity** in a gas in equilibrium is zero. The term is often used, however, to indicate the mean speed, in which case the values of c are averaged without regard to sign. It may then be shown from the **Maxwell-Boltzmann distribution law** that the mean molecular velocity is

$$\bar{c} = \sqrt{\frac{8kT}{\pi m}}$$

MOLECULAR VELOCITY, MEAN-SQUARE. If an assembly of particles contains a number n_1 moving with velocity c_1, n_2 with velocity c_2, $\cdots$, etc., the mean square velocity $\overline{c^2}$ is defined as

$$\overline{c^2} = \frac{n_1c_1^2 + n_2c_2^2 + \cdots}{n_1 + n_2 + \cdots}.$$

This quantity appears, for example, in the expression for the pressure of an ideal gas according to the kinetic theory. It can be shown from the **Maxwell-Boltzmann distribution law** that the mean square velocity is connected with the mean velocity (see **molecular velocity, mean**) by the relation

$$\overline{c^2} = \frac{3\pi}{8}(\bar{c})^2 = \frac{3kT}{m}.$$

MOLECULAR VELOCITY, MOST PROBABLE. If the function given by the **Maxwell-Boltzmann distribution law** is plotted against the velocity c, a smooth curve is obtained which has a maximum at a value of c which may be denoted by α, where α is called the most probable velocity. It increases with temperature, and is connected with the mean velocity (see **molecular velocity, mean**) by the relation

$$\bar{c} = \frac{2\alpha}{\sqrt{\pi}}.$$

MOLECULAR VOLUME OR MOLAR VOLUME. The volume occupied by one **mole** of a solid, liquid or gas, which is found by dividing the molecular weight by the density. One mole of any substance contains 6 0253 $\times$ 10^{23} molecules (the **Avogadro constant**).

MOLECULAR WEIGHT. The relative mass of a compound, calculated on the basis of an atomic weight for oxygen of 16, and obtainable by adding the atomic weights of the elements in the compound, multiplying each atomic weight by the number of atoms of that element present in the formula of the compound. (1) If atmospheric oxygen is taken as the reference standard (atomic weight = 16), the molecular weight obtained is called the chemical molecular weight. (2) If the oxygen isotope of mass number 16 is taken as the standard, the molecular weight obtained is called the physical molecular weight.

MOLECULE. The smallest particle of any substance that can exist free and still exhibit all of the chemical properties of the original substance

MOLECULE. ACTIVATED. A molecule containing one or more excited atoms. (See **atom, excited.**)

MOLECULE, ISOSTERIC. One of two or more molecules possessing essentially the same **valence** configuration, usually the same **total** number and arrangement of valency electrons.

MOLECULE, HOMONUCLEAR. A molecule composed of atoms whose nuclei are identical in charge and mass.

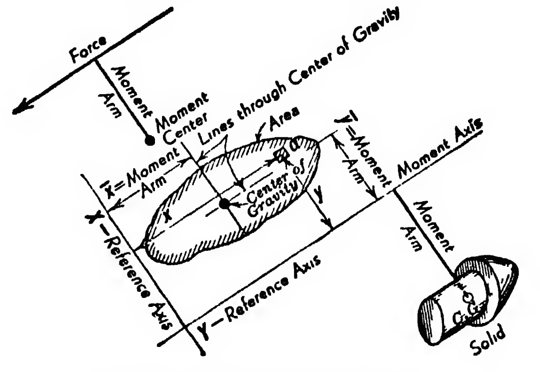
MOLLIER DIAGRAM. The properties of a vapor, as recorded in vapor tables, may be displayed graphically in a number of ways, among which the most used, and probably the most valuable, is the charting upon a plane whose coordinates are **enthalpy** or **total heat** and **entropy.** Generally, the **total heat is**

made the **ordinate,** and entropy the **abscissa.** This chart of the properties of vapor is named the Mollier Diagram, and is of considerable use in tracing both theoretical and actual expansions of vapor. A throttled expansion on the Mollier Diagram is parallel to the constant heat lines, and adiabatic expansion is parallel to the constant entropy lines. Pressure, quality or superheat, and total temperature are shown on the Mollier Diagram as series of lines curved and inclined to the axes. Thus all characteristics of a vapor except volume may be displayed on the Mollier Diagram.

MOLYBDENUM. Metallic element. Symbol Mo. Atomic number 42.

MOMENT. Moment consists of the product of a quantity and a distance to some significant point connected with that quantity. The principal moments are moments of forces, moments of lines, moments of areas, and moments of masses. Two types of moments are statical moment and the **moment of inertia.** Unless specificially stated to be otherwise, the word moment would be taken to mean statical moment. A physical picture of moment may be obtained by considering the moment of a **force** (called torque). It is the magnitude of the force multiplied by the moment arm which is a perpendicular dropped from the moment center to the line of action of the force This moment is the turning effect on a body against which the force is applied. The moment of an area is the magnitude of the area multiplied by the perpendicular distance from the centroid of the area to the axis of moments. Similarly the moment of a solid is its weight multiplied by the distance from its center of mass to the axis of moments.

The summation of moments of a force enters into one of the three equations of statical equilibrium. In a case of equilibrium, this summation must always equal zero about any chosen moment center. The moment of an area about a line is of use in finding the centroid of an area, since the magnitude of the area multiplied by the distance to a parallel line through the centroid must equal the summation of all the incremental areas multiplied by the perpendicular distances from the centers of these areas to this reference line. Thus in the irregular figure shown the distance from the Y-reference axis (any convenient line) to a parallel line through the centroid of the figure is determined by summing the elementary moments, i.e.,



Moments of force, area and mass

ay, and equating the summation to the product of the total area, A, and the centroidal distance $\bar{y}$.

$$\bar{y} = \frac{\text{Summation of } ay}{A}.$$

In a similar manner the location of a line, through the center of gravity, may be obtained in relation to the X-reference axis (any other convenient line not parallel to the Y-reference line). That is

$$\bar{x} = \frac{\text{Summation of } ax}{A}.$$

The intersection of these two lines, whose location is given by $\bar{x}$ and $\bar{y}$, is the center of gravity of the area. The center of gravity of a solid may be found in a similar manner by the use of three reference axes

The use of the statical moment in finding centroid of areas or masses extends to areas and shapes which are made up of a number of elementary areas or masses whose centroids are common knowledge. Thus a trapezoid could be considered as made up of two triangles; a rivet, of a hemisphere and a cylinder This method is also useful in computing centroids when the outline of the figure is expressed by a mathematical equation, since then the summation of ax and ay may be obtained as definite integrals. Cases of irregular figures which would not be analyzable by either of these methods can be treated by graphical means.

MOMENT OF FORCE. The product of the magnitude of a force, and the perpendicular distance from the line of action of the force to a point which is the center of the rotation induced by that force.

MOMENT OF INERTIA. See **inertia, moments and products of.**

MOMENT OF INERTIA, PRINCIPAL. See **inertia, moments and products of.**

MOMENT OF MOMENTUM (ANGULAR MOMENTUM). For a collection of particles and a given origin, the quantity

$$\mathbf{r}_j \times \left(m_j \frac{d\mathbf{r}_j}{dt}\right)$$

is called the moment of momentum of the jth particle about the origin, where $\mathbf{r}_j$ is the position vector from origin to jth particle; m_j is the mass of jth particle; $\frac{d\mathbf{r}_j}{dt}$ is the time rate of change of position vector; $\times$ indicates the vector cross product operation. (See **momentum; vector cross product.**)

For a rigid body, the total moment of momentum is designated as the angular momentum and written

$$\begin{aligned}\mathbf{H} = \mathbf{i}(\omega_x I_{xx} - \omega_y I_{xy} - \omega_z I_{xz}) \\ + \mathbf{j}(-\omega_x I_{yx} + \omega_y I_{yy} - \omega_z I_{yz}) \\ + \mathbf{k}(-\omega_x I_{zx} - \omega_y I_{zy} - \omega_z I_{zz})\end{aligned}$$

where ω_x, ω_y, ω_z are components of angular velocity; I_{xx}, I_{yy}, I_{zz} are moments of inertia; and I_{xy}, I_{xz}, etc., are products of inertia. (See **inertia, moments and products of;** and **angular momentum.**)

MOMENTUM. For a single particle of mass m whose position vector is $\mathbf{r}$ the momentum is the vector quantity

$$m\frac{d\mathbf{r}}{dt} \text{ or } m\mathbf{v}, \text{ where } \mathbf{v} = \frac{d\mathbf{r}}{dt}$$

is the velocity. For a system of n particles of masses $m_1 \cdots m_n$ respectively and position vectors $\mathbf{r}_1 \cdots \mathbf{r}_n$ respectively the total momentum is

$$\sum_{i=1}^{n} m_i \cdot \frac{d\mathbf{r}_i}{dt}.$$

From the fundamental principles of mechanics, the time rate of change of the total momentum of a system of particles is equal to the vector sum of all the external applied forces. For a system subject only to the initial interaction forces between the particles, the total momentum remains constant. (See **momentum, conservation of.**)

MOMENTUM, CONSERVATION OF. For a dynamical system consisting of n material particles of masses $m_1, m_2 \cdots m_n$ respectively and position vectors $\mathbf{r}_1, \mathbf{r}_2 \cdots \mathbf{r}_n$ respectively, if the only forces acting are the mutual interaction forces of the particles the total momentum of the system remains constant; for example,

$$\Sigma m_i \frac{d\mathbf{r}_i}{dt} = \text{constant}.$$

The law of conservation of momentum is as fundamental to physics as the law of **conservation of mass** or the law of **conservation of energy.** Like these laws, it holds in **quantum theory** and **relativity theory** as well as in more classical theories.

MONAURAL. Pertaining to a single-channel audio channel.

MONIMAX. Trade name for a high-permeability magnetic alloy composed of 50% iron, 47% nickel and 3% molybdenum.

MONITOR. (1) An **ionization chamber** mounted in an x-ray beam and connected to a continuously reading instrument, to serve as an indicator of constancy of x-ray output. (2) An ionization chamber used to detect the presence of undesirable radiation in connection with health protection. (3) To check by means of a receiver the operation of a telephone, radio, television or similar transmitter in order to ascertain the quality of transmission, fidelity to a frequency band, etc. The device used for (3), or the action of using the devices (1) and (2).

MONITOR, AIR. See **air monitor.**

MONITOR, AMPLITUDE-MODULATION. A device to measure and to indicate continuously the percentage modulation of amplitude-modulation transmitters. In addition to measurement of percentage of negative or positive modulation-peaks, commercial devices may also provide provisions for measuring program level, carrier shift due to **modulation,** and transmitter audio-frequency response.

MONITOR, AREA. Any device used for detecting and/or measuring radiation levels at a given location for warning or control purposes.

MONITOR, CATHODE-RAY OSCILLOSCOPE. An **oscilloscope** used to monitor the synchronizing and video waveforms of television transmissions.

MONITOR, FREQUENCY - DEVIATION. See **monitor, frequency-modulation.**

MONITOR, FREQUENCY-MODULATION STATION. A monitor (see **monitor (3)**) for commercial FM stations and the aural channel of television transmitters. The quality of transmission, as well as the carrier frequency, are monitored.

MONITOR, PHASE. An instrument designed for use in adjustment and operation of directional antennas (see **antenna, directional**) It measures phase difference and ratio of magnitudes of antenna currents.

MONITOR, PICTURE. A **kinescope** employed to observe the characteristics of television video transmission.

MONITOR, PROGRAM. A monitor (see **monitor (3)**) used to observe the quality of transmission In broadcasting, it usually consists of a complete high-quality receiver which actually monitors the transmitter output.

MONITORING. Periodic or continuous determination of the amount of ionizing radiation or radioactive contamination present in an occupied region, or in a person, as a safety measure for purposes of health protection. Area monitoring: Routine monitoring of the level of radiation or of radioactive contamination of any particular area, building, room or equipment. Usage in some laboratories or operations distinguishes between routine monitoring and survey activities. Personal monitoring: Monitoring any part of an individual, his breath, or excretions, or any part of his clothing.

MONKEY CHATTER. The peculiar garbled sound resulting from **cross-modulation** between the sidebands of a strong adjacent-channel signal and the carrier of the desired signal.

MONOCHROMATIC. (1) Having one color, strictly one frequency or wavelength of optical radiation. Actually no finite amount of radiation will ever be strictly monochromatic. It will, at best, contain a narrow band of frequencies. (2) By analogy, a beam of particles, such as β-particles or neutrons, is said to be monochromatic if all the particles have the same, or nearly the same, energies.

MONOCHROMATIC EMISSIVITY. See **emissivity.**

MONOCHROMATIC ILLUMINATOR. An instrument used to supply a beam of light having some desired, narrow range of wavelengths; sometimes called a "monochromator." The common form resembles a prism **spectroscope.** White light, entering the fixed collimator as usual through a narrow slit, is dispersed by a suitably-shaped prism, the resulting spectrum falls on a metal plate, and a second narrow slit allows "monochromatic" light (actually light of a narrow range of wavelengths) to emerge. This apparatus is particularly useful (with proper choice of material composing prism and lenses) for radiation outside of the visual or photographic range, where the detector is some type of phototube, as, for example, a thermocouple or photoconductive detector.

In addition to the simple monochromatic illuminator described above, there are a number of instruments using two or more prisms and, sometimes, more than two slits. These may offer greater purity of the emergent light, but are otherwise identical in principle

MONOCHROMATOR. The same as monochromatic illuminator.

MONOCHROME BANDWIDTH (OF THE SIGNAL). The video bandwidth of the **monochrome signal.**

MONOCHROME BANDWIDTH (OF THE MONOCHROME CHANNEL). The video bandwidth of the **monochrome channel.**

MONOCHROME CHANNEL. In a color-television transmission, any path which is intended to carry the **monochrome signal.** The **monochrome channel** may also carry other signals; for example, the **carrier color signal** which may or may not be used.

MONOCHROME SIGNAL. In monochrome television transmission, a signal wave for controlling the **luminance** values in the picture, but not the **chromaticity values. In color**

television transmission, that part of the signal wave which has the major control of the luminance of the color picture, and which controls the luminance of the picture produced by a conventional monochrome receiver.

MONOCHROME TRANSMISSION. In television, the transmission of a signal wave for controlling the **luminance** values in the picture, but not the **chromaticity** values.

MONODISPERSE SYSTEM. A system of **colloidal** particles in which the value of the **sedimentation constant** is constant for successive time intervals, indicating that the system comprises particles of uniform size.

MONOGENIC. See **analytic.**

MONOMER. A single molecule, or a substance consisting of single molecules. The term monomer is used in differentiation of dimer, trimer, etc., terms designating polymerized or associated molecules, or substances composed of them, in which each free particle is composed of two, three, etc , molecules.

MONOMOLECULAR LAYERS. (See also **unimolecular layers; surface film.**) The early work of Rayleigh, Langmuir, Hardy and others has shown that it is possible to deposit films on solid or liquid surfaces which are one molecule thick. Any such layer is called a monomolecular layer, unilayer or monolayer. For example, long-chain polar compounds at an air-water interface may form an oriented monomolecular layer in which the polar end group is attached to the water surface With such compounds it is in fact not possible to obtain films thicker than monomolecular layers, and if a drop of a fatty acid or long-chain alcohol, for example, is placed on a clean water surface it spreads to form a monolayer in equilibrium with the lens of excess compound. Some monomolecular films, such as the long-chain alcohols, when deposited on a water surface, have been found to reduce the rate of evaporation of water to a considerable extent. Monomolecular layers may also form at oil-water interfaces and play an important part in the formation of **emulsions.** The orientation of the monomolecular layer on the surface depends on the structure of the molecule and the density of packing on the surface.

Monolayers may be transferred from a water to a solid surface by the Langmuir-Blodgett dipping technique, and by successive dippings multimolecular films or multilayers are formed. Such multilayers are often unstable and recrystallize on the surface.

In the **adsorption** of gases and vapors on solids, monolayers are also formed provided the pressure of the gas or vapor is not too high. If the pressure is higher than about one-fifth the saturated vapor pressure, the layer frequently becomes more than one molecule thick.

MONOMORPHIC. Having one form, i.e., one **crystal form.**

MONOSCOPE. A signal-generating, electron-beam tube in which a **picture** signal is produced by **scanning** an electrode, parts of which have different secondary-emission characteristics For example, a television **camera-tube** that contains a fixed pattern, and is used to produce pre-broadcast test patterns for testing and alignment purposes.

MONOSTABLE. Referring to a circuit with one stable, and one quasi-stable state. The circuit requires one trigger to perform a complete cycle.

MONOTRON. Synonym for **monoscope.**

MONOTROPY. The property of a substance by which it occurs only in one form (commonly only one solid form).

MONOTROPY, PSEUDO The phenomenon of the existence of a substance in a plurality of forms all but one of which are unstable or metastable under practically all conditions, or under all ordinary conditions.

MONSOON. Seasonal winds which blow with great steadiness, reversing their direction with the change of season. In summer their direction is generally toward the large heated land areas, rushing in to displace the great volumes of air rising in convective currents. In winter they blow, with less force, outward from the great areas of ice and snow toward the tropics, or out over the surface of the warmer ocean.

MONTE-CARLO METHOD. A method of solution of a group of physical problems by

means of a series of statistical experiments which are performed by applying mathematical operations to random numbers. This method applies most directly to stochastic problems.

MONTGOMERY NOISE TRANSMISSION EFFECT. When three successive points are taken along a **semiconduction** filament, the **noise voltages** V_{12}, V_{23}, V_{13} do not combine so that the noise power V_{13}^2 equals the sum of V_{12}^2 and V_{23}^2. This is interpreted as being due to the **lifetime** of a **hole** being so long that most of the holes entering the first segment also enter the second, and hence the voltages themselves should be added. (See **filament noise.**)

MOPA. Abbreviation for **master-oscillator power-amplifier.**

MORERA THEOREM. The converse of the **Cauchy integral theorem.** If $f(z)$ is a continuous function of the complex variable z, and if

$$\int_C f(z)dz = 0$$

for any closed contour in the complex plane, then $f(z)$ is an **analytic function.**

MORGAN EQUATION. A modification of the Ramsay-Shields equation, of the form:

$$\gamma(Mv)^{2/3} = A + Bt + Ct^2$$

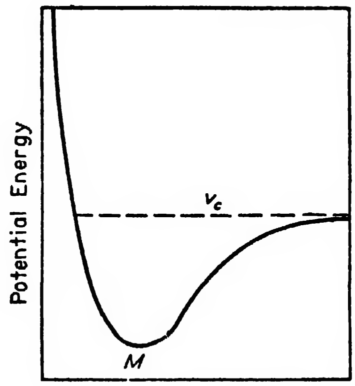
where γ is the surface tension of a liquid at any temperature, M is its molecular weight, v is its specific volume at temperature t, $\gamma(Mv)^{2/3}$ is the molar surface energy, A and C are constants, and $B = 2C(t_c - 6)$, where t_c is the critical temperature.

MORPHOTROPY. In crystals the change in the ratio in the length of the axes caused by changes in molecular structure such as substitution of certain radicals.

MORSE EQUATION. An equation relating the potential energy of a diatomic molecule to the internuclear distance. It is of the form

$$U(r) = D(1 - e^{-a(r-r_e)})^2$$

where $U(r)$ is the potential energy for an internuclear distance r, measured from the lowest point (M) of the curve in the figure, as zero; the equilibrium distance, i.e., at M is r_e and D is the dissociation energy, corre-



sponding to the level V_c, also measured from the lowest point; a is a constant Every electronic state has a different potential energy curve.

MORSE POTENTIAL. See **Morse equation.**

MOSAIC. In television, the photosensitive surface in an **iconoscope,** or **orthicon camera-tube.** In this tube the light rays are transformed into equivalent electrical charges.

MOSAIC STRUCTURE. Evidence from **x-ray analysis** suggests that even an annealed **single crystal** is usually composed of a mosaic of blocks of the order of 5000 A in dimension and tilted to one another at angles of the order of 10 minutes

MOSELEY LAW. The frequency of a line belonging to a particular series of characteristic **x-rays** is quantitatively related to the atomic number Z of the target element by the expression:

$$\nu^{1/2} = a(Z - \sigma)$$

where a is a proportionality constant and σ is the same for all the given series, thus for the K_α lines, σ is 1.0, and for the L_α line, σ is 7.4.

MOSELEY NUMBER (Z). The **atomic number.**

MOSELEY PLOTS FOR X-RAY LEVELS. Graphical relationships in which the square root of the frequency of characteristic lines of a given **x-ray series,** is plotted against the atomic numbers of the elements producing the x-rays. With fair accuracy these plots

are straight lines, not only for the K_α lines of the elements, but also for L_α lines, M_α lines, etc., thus demonstrating the relationship between the characteristic x-rays emitted by an element, and its **atomic number** or some closely related quantity such as nuclear charge.

MOST PROBABLE MOLECULAR VELOCITY. See **molecular velocity, most probable.**

MOTHER. A groove structure formed by electroplating a thin layer of metal onto a pressing formed by a master, and thus constituting the second step in the manufacture of a phonograph record. The mother is used to manufacture the stamper.

MOTION. A change in position with respect to a reference system of a material particle or aggregate of such particles.

MOTION BACKWARDS IN TIME. See **Feynman diagram.**

MOTION, CONSTRAINED. A form of **motion** in which the geometry of the environment compels the particle or object to move on a specified curve or surface

MOTION, EQUATIONS OF. A set of equations, generally in differential form, which when solved yield information concerning the subsequent motion of a particle or system of particles whose initial conditions are known The initial conditions are specified by the initial position and initial velocity A knowledge of the resultant force acting on the system at any instant is also necessary. There are several equivalent forms in which the equations of motion may be expressed (See **Newton equations of motion; Lagrange equations of motion; Hamilton canonical equations of motion;** and **Euler equations of motion (for rotational motion); kinematics.**)

MOTION, HEISENBERG EQUATION OF. See **Heisenberg equation of motion.**

MOTION OF A SPHERE IN AN INCOMPRESSIBLE FLUID, EQUATION OF. The equation obtained by equating the mass-acceleration product to the sum of the gravitational, buoyancy and hydrodynamic forces on the sphere. If the **Reynolds number** of flow is low, the hydrodynamic forces are proportional to the velocity of the sphere and are given by the **Stokes law.** At large Reynolds numbers the resistance is more nearly proportional to the square of the velocity.

MOTION OF A SPRING. For a spring in which to a good approximation the restoring force is directly proportional to the displacement, the motion is simple harmonic. (See **simple harmonic motion.**)

MOTION, OSCILLATORY. Persistent motion which is confined to a finite region of space. Such motion is not necessarily periodic (see, for example, **Lissajous figures**), but when it is, there is precise repetition after the elapse of a finite time called the period. The motion of a pendulum, of a weight on a stretched spring and of a point in a plucked string are examples of oscillatory motion. (See **oscillator.**)

MOTION, PARAMETRIC EQUATIONS OF. In certain cases of motion in two and three dimensions, the solutions of the differential equations of motion yield the displacements of the components along the coordinate axes as a function of time with the general form of these parametric equations:

$$x = f_1(t)$$
$$y = f_2(t)$$
$$z = f_3(t).$$

These are called parametric equations of the path with the time t as the parameter. To determine the path of the motion in the particular two or three dimensional space, it is necessary to eliminate the time and obtain a function of the form $\Phi(x,y,z) = 0$

The motion of a projectile and the composition of simple harmonic motions in a plane are examples (See **kinematics.**)

MOTION-PICTURE FILM SOUND-REPRODUCING SYSTEM. The sound record of a motion picture film is carried on the sound track, a strip 0.1 in. wide on a 35 mm film. In recording the sound track, two systems are generally used. In the variable-area system the transmitted light amplitude is a function of the amount of unexposed area in the positive print. In the variable-density system the transmitted light amplitude is an inverse function of the amount of exposure in the positive print. For reproduction of the sound, light is passed through the film onto a photocell. The amount of light which impinges on

the photocell is proportional to the unexposed portion of the sound track in variable-area recording, or to the inverse function of the density in variable-density recording. When the film is in motion, the light undulations which fall upon the photocell correspond to the voltage variations applied to the recording device.

MOTION, SIMPLE HARMONIC. Motion in which the particle is attracted towards an origin by a force directly proportional to the instantaneous distance of the particle from the origin. The resulting periodic motion is characterized by a space-time graph of simple sine form.

The differential equation of motion is

$$m\frac{d^2x}{dt^2} = -kx$$

where m is the mass of the particle, k is the constant of proportionality (**stiffness coefficient**), x is the displacement from origin.

The solution of the differential equation yields the displacement as a function of the time.

$$x = A \begin{matrix}\sin \\ \cos\end{matrix} \{2\pi ft + \epsilon\}$$

where A is the amplitude of motion, f is the frequency $= (1/2\pi)\sqrt{k/m}$, ϵ is the **epoch** determined by the value of the function at $t = 0$.

The projection of a particle moving in a circle of radius A and with frequency f onto any straight line in the plane of the circle travels according to the above sinusoidal formula. This is called the circle of reference. (See **harmonic oscillator.**)

MOTION, VIBRATORY. See **oscillatory motion.**

MOTIONAL IMPEDANCE. See **impedance, motional.**

MOTORBOATING. The occurrence of a very low frequency oscillation in an **amplifier** (especially audio) due to an undesirable amount of **positive feedback.**

MOTOR EFFECT. The repulsion force exerted between adjacent conductors carrying currents in opposite directions.

MOTOR, ELECTRIC. A machine which, receiving electrical energy, converts it into mechanical energy. Since there are so many different types of electric motors, it seems logical to begin a discussion of them with some attempt at classification of the principal types. Such a classification is given below, and includes the major types in present-day use.

A. Direct-current types.
   1. Shunt. } Straight or Interpole
   2. Series. } Straight or Interpole
   3. Compound. } Straight or Interpole
B. Alternating-current types.
   1 Synchronous.
   2. Induction.
      a. Polyphase.
         (1) Squirrel-cage rotor.
         (2) Wound rotor.
            (a) Slip ring.
            (b) Brush shifting.
      b. Single-phase.
         (1) Split-phase.
         (2) Repulsion-induction
         (3) Condenser
      c. Universal (series).

Electric motors are built in a range varying from outputs of $1/100$ of a **horsepower** up to well over 1000 hp A 50-hp motor is considered a large one, and the majority of electric motors now in use ranges between $1/4$ and 10 hp Standard motor sizes above the small fractional sizes are $1/4$, $1/3$, $1/2$, $3/4$, 1, $1\frac{1}{2}$, 2, 3, 5, $7\frac{1}{2}$, 10, 15, 20, 25, 30, 40, and 50-hp Sixty-cycle synchronous speeds are 3600, 1800, 1200, 900, 720, 600, 514, and 450 rpm. Full-load induction motor speeds are 2 5% less than these The efficiency of the electric motor ranges from 75 95%. It is higher in large motors than in small. Induction motors are more efficient the higher the rated speed, but d-c motor efficiency is little affected by speed. Efficiency is often secondary to reliability; nevertheless, it is a factor to be considered, particularly if the drive is heavy and the motor is well loaded over a considerable part of the time. **Direct-current** motors are much less frequently employed than **alternating-current,** because of the preponderance of a-c over d-c systems. However, speed control and starting torque are so excellent with d-c that it is frequently used in a-c territory where these characteristics are important. D-c power for motors is commonly obtained from the a-c supply through motor-generators, **mercury-arc tubes,** or grid-controlled **rectifiers,** with voltages ranging from 110 to

600. The extra expense of the converter installation lays some handicap upon the employment of d-c motors, and a number of methods have been devised to vary the speed of a-c types, but, in the main, the latter are constant speed. The shunt motor has a wound **armature,** the ends of the windings of which are brought to a **commutator,** upon which rest **brushes.** The incoming leads are connected to these brushes so that the line voltage is impressed across the windings of the armature. The stationary **field coils** are connected across the brushes in shunt arrangement so that they receive a constant voltage. When the motor is running, the coils of the armature cut the lines of force of the magnetic **field,** and so generate an internal voltage known as the counter-electromotive force. The sum of this counter-electromotive force and the resistance drop through the armature must equal the impressed voltage. Consequently the current taken is much larger when the motor is revolving slowly than when it is up to speed. This also explains why weakening the shunt-field current (and thereby the lines of force) causes the armature to increase its speed, since the weakened field causes less counter-voltage, hence allows more current to flow in the armature. Then more torque is produced, which increases the speed until the back voltage allows just the right current to flow to carry the existing load. The torque of the motor is produced by the magnetic reaction existing between the magnetism of the stationary field and the electromagnetic field surrounding the armature conductor.

Unlike the shunt motor, whose field current is practically constant at all speeds, the series motor produces a field which is maximum during starting and decreases as the motor comes up to speed. For this reason, the series motor has a powerful starting torque, and is used for hoists, traction motors, and the like. The shunt motor is essentially a constant-speed type; the series, a variable speed type. A motor having better speed regulation and starting torque can be obtained by a compound winding having both shunt and series fields. However, the simplicity of the shunt-field motor, coupled with the possibility of effecting a reasonable variation in speed by a variable resistance in the field circuit, has caused it to be widely used. It has been found, though, that any considerable weakening of the field is accompanied by sparking at the commutator, due to the demagnetizing **armature reaction.** Small poles, located between the shunt-field poles, and wound with series coils, will compensate for the distortion of the field flux, and such motors are known as interpole motors. (See **interpole.**)

In the a-c field, the above classification shows a primary division into synchronous and induction types. Of these, the **induction motor** is by far the more important; but the strictly constant speed feature of the synchronous motor has caused its selection in certain cases. The **synchronous motor** is practically an **alternator** operated inverted. It has a polyphase stator winding which carries the main line current. The field is wound on the rotor and is excited by d-c brought to it by brushes resting on slip rings. The synchronous motor is stable only when operating at a synchronous speed corresponding to the frequency of the system, and if it is loaded to where it lags ever so slightly behind this synchronous speed, it quickly "falls out of step" and comes to rest. The disadvantages of the synchronous motor are principally two: (1) Its constant speed. (2) It requires d-c excitation. Modern construction of polyphase synchronous motors results in good starting torque. The single-phase synchronous motor has no starting torque, but with three-phase the motor may be made self-starting if copper bars similar to the rotor of a squirrel-cage motor are embedded in the rotating field and connected to end rings. To start the motor, the d-c field is open-circuited and the stator windings connected to the line. The motor will then come up to speed, operating as a squirrel-cage induction motor, after which the field current may be applied, upon which the rotor will lock itself into step with the frequency of the system. A synchronous motor is generally used only in large sizes where it has the advantage of providing some power factor correction, since one of the characteristics of this motor is that a leading current will be drawn if the d-c field is overexcited, and this can be adjusted to neutralize the lagging current drawn by induction type motors.

The three-phase squirrel-cage motor is the simplest and most reliable electric motor made. It has a powerful starting torque, and good efficiency, and would probably replace

all other types were it not for the following reasons: It is essentially a constant speed motor, it draws a lagging current, and it is not built single-phase The stationary windings are connected either in **Delta** or **Y**, as may suit the individual design, and are so arranged as to produce a rotating field in the space occupied by the rotor. The rotor is a shaft upon which is built up a laminated steel core carrying embedded in its surface copper or aluminum bars which are parallel to the shaft. The inductive action of the field on this "cage" (if the core were removed, the bars would resemble the familiar squirrel exercising cage) sets up in the latter induced currents whose magnetic field reacts against the rotating field set up by the stator winding, producing a torque. If the rotor were turning in synchronism with the rotating field there would be no induction and no rotor currents. Therefore it is seen that the rotor cannot possibly operate it at full synchronous speed, even though idling. The difference in speeds is expressed by slip, i e, difference in speeds divided by synchronous speed, and a certain amount of slip is necessary to secure inductive action. As mentioned before, this varies from 2-5% of synchronous speed A squirrel-cage motor with rotor blocked acts like a transformer with short-circuited secondary, thus explaining the high starting torque.

There are installations where a polyphase motor is wanted, having some degree of speed control, and which may be brought up to speed more slowly than is customary with the squirrel-cage motor. For this service the more expensive wound-rotor and brush-shifting types may be used on three-phase circuits The wound-rotor principle is employed chiefly on large motors As its name implies, the wound rotor has polar windings in the rotor, the ends of which are joined either in Y or Delta, and brought to three slip rings. The currents induced in the rotor are brought out through these slip rings to an external three-phase resistance, which may be varied at will from zero to maximum The operation is much like that of a squirrel-cage motor, except that, for starting, the rotor current is decreased by inserting the maximum of resistance in the external circuit. This is gradually decreased as the motor comes up to speed, until all of the resistance is short-circuited and the motor is operating inductively with a normal slip. Given constant torque, this motor may be varied in speed by varying the external resistance, but it is somewhat less efficient than the brush-shifting type, because of the energy consumed in the resistance. The brush-shifting motor is used where considerable speed variation is desired at good efficiency, as, for instance, when driving fans or pumps of large size. The brush-shifting motor has the primary winding on the rotating armature, similar to d-c practice. This winding is connected to the three-phase line through slip rings. Another winding, called an adjusting winding, is also placed on the rotor; in fact, in the same slots, but is connected with a commutator, which is made fairly wide The three-phase stator secondary windings are brought out individually to six brushes which bear on the commutator, and are connected as shown in the diagram. Each set of three brushes is joined by a yoke, so that they may be moved simultaneously, and each pair is placed on opposite ends of the commutator. When these yokes are moved with respect to one another, they cause to be included a certain number of commutator segments in each secondary coil. When each pair of brushes is on a common commutator bar, the motor runs as a straight induction motor at slip frequency. By moving the brushes apart by rotating a yoke, the voltage induced in the commutator coil is added to that in the secondary, and the motor speeds up These voltages may be subtracted by moving the brush in the opposite direction, resulting in slowing down the motor. Since the forces needed to move the yoke are very small, it may be readily operated by the light pressures produced in an automatic control system.

Turning next to the single-phase motor, it is entirely possible for a single-phase motor to operate inductively like the squirrel-cage motor, provided it can be brought up to speed, but a single-phase squirrel-cage motor has no starting torque, so there have been developed numerous ways of doing this for single-phase motors, most of which are of small size. In the split-phase motor, an inductance and resistance are used to displace the voltage at the mid-point so as to get an arrangement resembling a two-phase impressed voltage. Of course the starting torque obtainable is inferior to that of a polyphase motor, but is sufficient to start a motor attached to a drive

requiring low starting torque. A fan illustrates this service. For heavy starting duty the starting torque of a single-phase motor is created by repulsion, which shifts over to induction as the motor comes up to speed. Several systems have been invented. In one, the armature windings are brought out to a commutator, upon which rest two brushes connected externally by a low resistance conductor. A stator winding is connected across the line. The short-circuited armature has induced in it the large current necessary to secure starting torque. As the motor comes up beyond a certain speed, a centrifugally operated switch lifts the brushes from the commutator and applies to it a ring which short-circuits all the segments. When this is done the motor operates as a straight induction motor. This principle, known as repulsion-induction—i.e., repulsion starting and induction running—is employed in most small motors which are to produce large starting torques on single-phase supply. Another type of repulsion-induction motor is less complicated mechanically. Here the switch operates during starting, and is closed for induction operation.

The condenser motor is a split-phase motor, having the phase displaced by capacitance rather than inductance. It is superior to the former in starting torque, efficiency, and power factor, but more expensive and slightly more bulky. The starting torque of the modern condenser motor compares favorably with the repulsion-start motors, and, since the cost is less, the condenser motor is replacing the repulsion type in many applications. In some of these motors the condenser is disconnected by a centrifugal switch after starting; in others it is left in the circuit to improve the operating characteristics and the power factor of the motor.

A universal motor is a series motor which may be operated on either d-c or a-c. It is usually employed in small sizes only, there being a compensating coil to prevent armature sparking and to improve the power factor.

MOTOR-TORQUE GENERATOR. A name sometimes used to identify a **synchro.**

MOTT SCATTERING FORMULA. A formula giving the differential cross section (see **cross section, differential**) for the scattering of identical particles by a **Coulomb interaction.** Thus, the cross-section $d\phi$ for the scattering of an electron of velocity $v \ll c$ through an angle between θ and $\theta + d\theta$ by another electron initially at rest, is given by the following relationship, which shows a departure from **Rutherford scattering** due to the indistinguishability of the two electrons:

$$d\phi = \frac{2\pi e^4}{m^2 v^4} [\operatorname{cosec}^4 \theta + \sec^4 \theta - \operatorname{cosec}^2 \theta \sec^2 \theta] d \cos 2\theta.$$

"MOUNTAIN EFFECT." The effect of rough terrain on radio-wave propagation, which causes reflected waves to react with the direct waves in a manner which obscures the true direction of the source. This effect creates one form of error in **radio direction-finding.**

MOVING-ARMATURE LOUDSPEAKER. See **loudspeaker, magnetic.**

MOVING BOUNDARY METHOD (FOR TRANSPORT NUMBER). A suitable sequence of electrolytes in a tube, say lithium chloride, potassium chloride, potassium acetate, will exhibit interfacial boundaries. On the passage of current, these boundaries will move, and their relative motion yields the transport numbers of the K^+ and Cl^- ions in the KCl solution.

MOVING-COIL GALVANOMETER. See **galvanometer, moving-coil.**

MOVING-COIL LOUDSPEAKER. See **loudspeaker, dynamic.**

MOVING-COIL MICROPHONE. See **microphone, dynamic.**

MOVING-CONDUCTOR LOUDSPEAKER. See **loudspeaker, moving-conductor.**

MOVING-CONDUCTOR MICROPHONE. See **microphone, moving-conductor.**

MOVING-IRON MICROPHONE. See **microphone, variable-reluctance.**

MOVING-IRON VOLTMETER. See **voltmeter, moving-iron.**

MOVING-TARGET INDICATOR. A **radar** presentation which shows only targets which are in motion. Signals from stationary targets are subtracted out of the return signal by the output of a suitable **memory circuit.**

MTI. Abbreviation for **moving-target indicator.**

MU. (1) Reduced mass (μ). (2) Micron (μ). (3) Millicron (mμ). (4) Micromicron ($\mu\mu$). (5) Nuclear Bohr magnetron (μ_I). (6) Electronic Bohr magnetron (μ_0). (7) Coefficient of friction (μ), of rolling friction (μ_r), of starting friction (μ_s). (8) Poisson ratio (μ). (9) Magnetic permeability or inductivity (μ). (10) Relative permeability (μ_r), permeability of free space (μ_0). (11) Electric moment of atom, molecule or dipole (μ or μ_e). (12) Magnetic moment of atom, molecule or dipole (μ or μ_m). (13) Joule-Thomson (Kelvin) coefficient (μ). (14) Refractive index (μ, but n is preferred). (15) Amplification factor (μ). (16) Grid control ratio (μ). (17) Chemical potential (μ). (18) Molecular conductivity (μ).

MU-FACTOR (OF AN *n*-TERMINAL ELECTRON TUBE). The ratio of the magnitude of infinitesimal change in the voltage at the jth electrode to the magnitude of an infinitesimal change in the voltage at an ith electrode under the conditions that the current to the mth electrode remains unchanged, and the voltages of all other electrodes be maintained constant. (See **amplification factor.**)

MUELLER BRIDGE. See **bridge, Mueller.**

MUELLER LAW. The difference between sensations is not in the nerve impulses, which are of the same kind for all senses, but to the activities in the portions of the brain to which the impulses travel. Color sensation, like other sensations, is subject to this law.

MULTIAR. A diode-controlled, regenerative-amplitude **comparator.** The name implies a certain configuration.

MULTICAVITY MAGNETRON. See **magnetron, multicavity.**

MULTICELLULAR HORN. See **horn, multicellular.**

MULTICHANNEL RADIO TRANSMITTER. See **transmitter, multichannel radio.**

MULTICHANNEL TELEVISION. A television system which divides the **video signal** information among several different transmitters occupying individual frequencies.

MULTIGROUP MODEL (NUCLEAR REACTOR). A model in which the neutron flux is divided into parts corresponding to several discrete energy ranges. Account is taken of the difference in spatial behavior of the different energy groups and also of transfer of neutrons between the various energy groups.

MULTINOMIAL. A polynomial. When raised to a power, it may be expanded by the multinomial theorem of which the binomial theorem is a special case. The formula for such an expansion is

$$(x_1 + x_2 + x_3 + \cdots + x_r)^n = \sum \frac{n!}{a_1!a_2! \cdots a_r!} x_1^{a_1} x_2^{a_2} \cdots x_r^{a_r}$$

where a_k is an integer and $\sum_{k=1}^{r} a_k = n$.

MULTIPATH TRANSMISSION. The condition in which the radio signal from a transmitter travels by more than one route to a receiver antenna. In television this results in the production of **ghosts.**

MULTIPLE-ADDRESS (INSTRUCTION) CODE. An instruction in general consists of a coded representation of the operation to be performed, and of one or more addresses of words in storage. The instructions of a multiple-address code contain more than one **address.**

MULTIPLE DECAY. See **branching.**

MULTIPLE DISINTEGRATION. See **branching.**

MULTIPLE GRATING. See **ultrasonic cross grating.**

MUTUAL-INDUCTANCE BRIDGE. See **bridge, mutual-inductance.**

MULTIPLE MODULATION. See **modulation, multiple.**

MULTIPLE REFLECTIONS. When a ray of light strikes a transparent plane-parallel plate, some of the radiation will be reflected, while some will enter the plate and be partly reflected back and forth between the two sides of the plate. At each reflection, some of the radiation will escape to the outside (provided the angle of the ray inside the plate with the normal to the surface is less than the **critical angle**). The radiation which is reflected on the first contact with the plate is of opposite phase with that which has entered and then been emitted from the entrant side. It can

be shown that the total energy of the first reflected beam is equal to the total of the other reflected light on the entrant side so that total **interference** occurs when $2nd \cos \phi = m\lambda$, n being the refractive index of the plate, d its thickness, ϕ the angle of incidence and $m\lambda$ an integral number of wavelengths. There is never total interference for the transmitted beam. (See **Fabry-Perot etalon** and **Haidinger fringes.**)

MULTIPLE SCATTERING. See **scattering, multiple.**

MULTIPLE TUBE COUNTS (IN RADIATION COUNTER TUBES). Spurious counts induced by previous tube counts.

MULTIPLE-TUNED ANTENNA. See **antenna, multiple-tuned.**

MULTIPLE-UNIT, STEERABLE ANTENNA. See **antenna, musa.**

MULTIPLE-UNIT TUBE. See **tube, multiple-unit.**

MULTIPLET INTENSITY RULES. Rules for the relative intensities of spectral multiplet lines: (1) The sum of the intensities of all lines of a multiplet which start from a common initial level is proportional to the quantum weight $(2J + 1)$ of the initial level. (2) The sum of the intensities of all lines of a multiplet which end on a common final level is proportional to the quantum weight $(2J + 1)$ of the final level.

MULTIPLEX. See **transmission, multiplex.**

MULTIPLEX, ASYNCHRONOUS. A multiplex transmission system (see **transmission, multiplex radio**) in which two or more transmitters occupy a common channel without provision for preventing simultaneous operation.

MULTIPLEX CHANNEL. A channel used in multiplex transmission. (See **transmission, multiplex radio.**)

MULTIPLEX RADIO TRANSMISSION. See **transmission, multiplex radio.**

MULTIPLEXING, METHODS OF. The three basic methods of multiplexing involve separation of the signals by time division, frequency division, or phase division.

MULTIPLICATION FACTOR OR CONSTANT, k (NUCLEAR REACTOR). The ratio of the number of neutrons present in a reactor at a given time to the number present one finite lifetime earlier. Sometimes called the effective multiplication constant. For a homogeneous medium the infinite (k) multiplication constant refers to the multiplication constants in an infinite medium. The multiplication constant minus one is called the excess multiplication constant. The condition for a self-sustaining chain reaction is that k be equal to or greater than unity.

MULTIPLICATION FACTOR, FERMI-WIGNER, CALCULATION OF. The calculation of the **multiplication factor** in terms of the **four-factor formula.**

MULTIPLICATION FACTOR, INFINITE. The value of the **multiplication factor** corresponding to a pile of infinite dimensions, or (approximately) to a pile of finite dimensions but no neutron leakage.

MULTIPLICATION FACTOR, PROMPT NEUTRON AND DELAYED NEUTRON PARTS OF TOTAL. In a reactor in which U^{235} is the fuel, **delayed neutrons** amount to about 0.75 per cent of the total neutrons. This introduces a "sluggishness" in the pile which makes control of the reactor feasible.

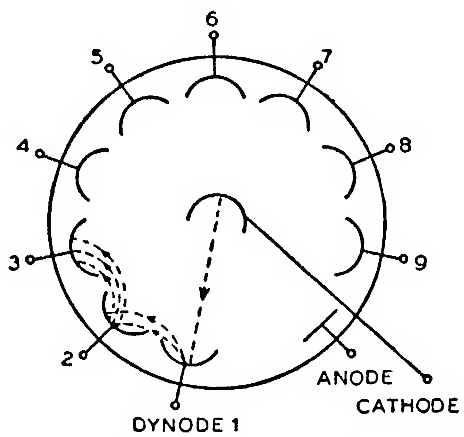
MULTIPLICITY. The number $2S + 1$, representing the number of ways of vectorially coupling the **orbital angular momentum** vector L with the **spin angular momentum** vector S of an atom. This value represents the number of relatively closely spaced energy levels or terms in an atom which result from the coupling process. The value of the **multiplicity** is added as a left superscript to the term symbol, as ^3P (triplet P), ^4D (quartet D), etc. The multiplicity of molecules is analogous to that of atoms, and is expressed also by the number $2S + 1$.

MULTIPLICITIES, ALTERNATION OF. Since the **multiplicity** for an atom is $2S + 1$, where S is the resultant spin of the electrons of the atom, and since S is integral or half integral for an even or odd number of electrons, respectively, it follows that the multiplicity of an atomic term is odd for an even number of electrons and even for an odd number of electrons. Therefore, even and odd

multiplicities alternate for successive elements in the periodic system. Incidentally, they alternate similarly in the series of ions with single and multiple charges for a given element.

There is an alternation of multiplicities for molecules just as there is for atoms. Molecules with an even number of electrons have odd multiplicities (singlets, triplets . . .) since S is integral, while molecules with an odd number of electrons have even multiplicities (doublets, quartets . . .) since S is half integral.

MULTIPLIER, ELECTRON. A device employed to amplify or multiply weak electron currents, such as those obtained from a **photoemissive cathode.** In the figure below, electrons are omitted from the cathode and ac-



Electron multiplier (By permission from "Electronics" by Williams, Copyright 1953, D. Van Nostrand Co., Inc.)

celerated to an electrode called a dynode, maintained at about 100 volts positive with respect to the cathode. Secondary electrons knocked out of the dynode are accelerated to a second dynode at a higher potential, and there still produces more secondaries. The cathode, nine dynodes and final anode used in typical multiplier cells are so placed and shaped that the electron beams are efficiently focused at each stage. In typical multiplier cells, the gain per dynode is between four and five. The total gain is $(4)^9$ to $(5)^9$ or about 10^6 In addition to their use in photocells, multipliers are used in some television **camera-tubes** and in radiation detectors.

MULTIPLIER, PHOTOELECTRIC. See **photoelectric multiplier.**

MULTIPOLE MOMENTS. The electric and magnetic multipole moments of a system in a given state ψ are measures of the charge, current, and magnet (via intrinsic spin) distributions in the state ψ, and determine the interaction of the system with weak external fields. In contrast with these static multipole moments, there are also transition multipole moments, which determine radiative transitions between two states and therefore depend on both states (see **multipole radiation**). Both kinds of multipole moments may be written as

$$Q_{l,m} = \int_r^l Y_{lm}^*(\theta\phi)\rho(r)dV$$

for the electric multipole moment of order l,m, and

$$M_{l,m} = \int_r^l Y_{lm}^*(\theta\phi)\rho \text{ div } M(r)dV$$

for the magnetic multipole moment of order l,m. In these formulas the function $Y_{lm}(\theta,\phi)$ is the normalized lm spherical harmonic, depending on ϕ as $e^{im\phi}$; $\rho(r)$ is the proper charge density; and $M(r)$ is the proper density of magnetization arising from moving charges and from intrinsic spin moments. The difference between static and transition moments is in the densities ρ and μ; for example, $\rho = e^{\Sigma|\psi(r)|^2}$ for the static case, and $\rho = e^{\Sigma\psi_f(r)\psi_i(r)}$ for the transition case between states i and f. The summations are over all charged particles.

MULTIPOLE RADIATION. The radiation field in free space may be expanded into electric and magnetic multipole fields, as well as into plane waves. Each multipole radiation field is characterized by the numbers l, m and by its **parity.** An electric multipole radiation, l, m, has a pure transverse magnetic field and a parity $(-1)^l$. A magnetic multipole radiation l, m has a pure transverse electric field and a parity $-(-1)^l$. A single photon of multipole radiation l, m, whether electric or magnetic, has an energy $h\nu$ and an angular momentum $l\hbar$, with component $m\hbar$ in the Z-direction. Multipoles with $l = 0$ do not exist; those with $l = 1$ are called dipole, those with $l = 2$, quadrupole, etc. The amplitudes of the various multipole radiations emitted by a moving charge and magnet distribution are proportional to the multipole moments of the distribution. In a nuclear transition, these

moments are dependent on the initial and final states.

MULTITRACK RECORDING SYSTEM. See **recording system, multitrack.**

MULTIVIBRATOR. A relaxation **oscillator** employing two electron tubes to obtain the in-phase **feedback voltage** by coupling the output of each to the input of the other through, typically, resistance-capacitance elements. The **fundamental frequency** is determined by the time constants of the coupling elements, and may be further controlled by an external voltage. When such circuits are normally in a nonoscillating state and a **trigger signal** is required to start a single cycle of operation, the circuit is commonly called a one-shot, a flip-flop, or a start-stop multivibrator.

MULTIVIBRATOR, ASTABLE. A **multivibrator** which can exist in either of two quasi-stable states, and switch rapidly from one state to the other

MULTIVIBRATOR, BISTABLE. A circuit with two stable states which requires two trigger pulses to complete one cycle. It is commonly referred to as a trigger circuit, Eccles-Jordan trigger circuit, or scale-of-two circuit.

MULTIVIBRATOR, MONOSTABLE. A **multivibrator** with one stable and one quasi-stable state. A trigger is required to drive the unit into the quasi-stable state, where it remains for a predetermined time before returning to the stable state. Sometimes referred to as the one-shot.

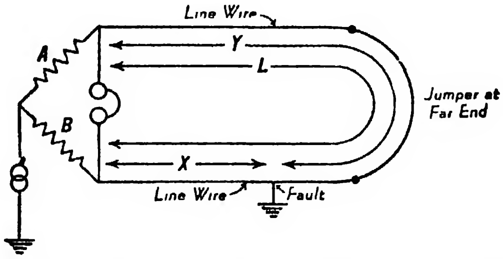
MUMETAL. A high-permeability, isotropic, magnetic alloy having approximately 78% nickel. Several different alloys with similar characteristics are manufactured under this name.

MUNSELL CHROMA. See **chroma.**

MUNSELL SYSTEM. A system of arranging and designating attributes of opaque surface colors.

MUON. The same as μ-meson. (See **meson.**)

MURRAY LOOP. A bridge type measurement made on communication **lines** to locate accidental **grounds.** As may be seen in the figure, it is a Wheatstone bridge in which the



line wires form two arms. The balance point gives

$$X = \frac{BL(r_1 + r_2)}{2r_2(A + B)}$$

where r_1 is the resistance per ft of the upper wire and r_2 of the bottom wire. Other quantities are shown on the diagram.

MUSA ANTENNA. See **antenna, musa.**

MUSICAL ECHO. See **echo, musical.**

MUTAROTATION. A phenomenon shown by freshly prepared solutions of certain sugars in which a change in **specific rotation** occurs upon standing. Some sugars show a decrease (i.e., glucose, 50%), whereas others (maltose) show an increase, of specific rotation. The change is not always in any special ratio.

MUTUAL CONDUCTANCE. One of the common vacuum-tube coefficients, which indicates the effect on the plate current of the grid voltage, other quantities being held constant. It is also known as the transconductance. Mathematically it is

$$G_m = [di_p/de_g]_{E_p \text{ constant}}$$

where di_p is an infinitesimal change of plate current and de_g is an infinitesimal change of grid voltage, while E_p is the plate voltage (see **transconductance; transadmittance**).

MUTUAL ENERGY BETWEEN MAGNETIZATION AND EXTERNAL FIELD. The work required to remove a magnetized body from a field under conditions of constant **magnetization.** It is given (per unit volume) by $E = HP_m$, where P_m is the magnetic polarization and H, the **magnetizing force.** In terms of intrinsic induction, $E = HB$ in rationalized systems of units, and by $E = H_rB/4\pi$ in unrationalized systems.

MUTUAL EXCLUSION, RULE OF. For molecules with a **center of symmetry**, transitions that are allowed in the infrared are forbidden in the Raman spectrum; and conversely, transitions that are allowed in the Raman spectrum are forbidden in the infrared.

MUTUAL IMPEDANCE. The **impedance** that is common to two **meshes** of a **network** is their mutual impedance. Equivalently, if a set of voltages and currents are related by

$$E_1 = Z_{11}I_1 + Z_{12}I_2 + \cdots Z_{1n}I_n$$

$$E_n = Z_{n1}I_1 + Z_{n2}I_2 + \cdots + Z_{nn}I_n$$

the coefficient $Z_{ij} = Z_{ji}$ is called the mutual impedance between the ith and jth meshes

MUTUAL INDUCTANCE. The ratio of **magnetic flux** linking a circuit to the current in another circuit producing said flux. (See **energy of a system of current circuits.**)

MUTUAL INDUCTION. See **electromagnetic induction.**

MUTUALITY OF PHASES, LAW OF. If two phases, with respect to a certain definite reaction, at a certain temperature, are in equilibrium with a third phase, then at the given temperature and for the same reaction, they are in equilibrium with each other.

MUTING SWITCH. A switch used to accomplish **intercarrier** noise suppression, especially in automatic tuning systems.

MYOPIA. A condition of the eye in which light from a distant object is focused by the relaxed eye at a point in front of the **retina.**

N

N. (1) Avogadro number (N). (2) Nitrogen (N). (3) Neutron (n). (4) Normal (solution) (N or n). (5) Number (n). (6) Number of molecules, atoms or nuclei (N), if kinds are plural ($N_{1,2\cdots}$). (7) Number of radioactive atoms at time t (N). (8) Number of radioactive atoms, initial (N_0). (9) Number of radioactive atoms, initial, if kinds are plural ($N^0{}_{1,2\cdots}$). (10) Number of components (phase rule) (n). (11) Total number of lines in a grating (N). (12) Number of molecules per unit volume (n). (12) Number of molecules per cm^3 under standard conditions (Loschmidt number) (N_0). (14) Number of moles (N). (15) Number of revolutions per unit time (n) (16) Number of turns of conductor (N). (17) Transport number (n). (18) Principal quantum number or shell number of an electron (n). (19) Direction cosines (l,m,n). (20) Refractive index (n), group refractive index (n_g). (21) Shear modulus of elasticity (n). (22) Total angular momentum of the electrons and nuclei, exclusive of spin (Hund's cases b, b' and d) (**N**).

N-ELECTRON. An electron characterized by having a **principal quantum number** of value 4. (See also **N-shell.**)

N-LINE. One of the lines in the N-series of **x-rays** which are characteristic of the various elements and are produced by excitation of the electrons of the **N-shell.**

N-RADIATION. One of a series of x-rays due to the excitation of electrons of the **N-shell.**

N-SHELL. The collection of all those electrons in the atom which have the **principal quantum number** 4. The N-shell is started with the element potassium, atomic number 19, which has one electron in its N-shell, and the N-shell is finally completed (containing 32 electrons) with the element lutecium, atomic number 71. During the progression from potassium to lutecium the difference between elements of consecutive atomic numbers is frequently not in the N-shell, but in an electron increment in the M-shell, or in the O-shell, or the P-shell.

***N*-TERMINAL NETWORK.** See **network, *N*-terminal.**

***N*-TERMINAL PAIR NETWORK.** See **network, *N*-terminal pair.**

N-TYPE SEMICONDUCTOR. A **semiconducting** material in which the conduction is mainly by negatively charged electrons.

NABLA. A name used for ∇, the **differential operator** generally called **del.** The shape of the symbol is thought to be similar to that of an Assyrian harp with that name.

NAPIER. See **neper (napier).**

NAPPE. See **conical surface.**

NARTB. Abbreviation for National Association of Radio and Television Broadcasters.

NATIONAL ELECTRONICS CONFERENCE. An annual conference held each October in Chicago Papers given at this conference are published as the Proceedings of the National Electronics Conference

NATIONAL TELEVISION SYSTEM COMMITTEE. A committee consisting of representatives from companies interested in television which, since its founding in 1940, has helped establish system standards in all phases of the industry.

NATURAL FREQUENCY. See **frequency, natural.**

NATURAL PERIOD. See **period, natural.**

NATURAL RADIOACTIVITY. Radioactivity exhibited by naturally occurring substances, in their natural state.

NATURAL RADIOACTIVE NUCLIDES. See **radioactive nuclides, natural.**

NAVIER - STOKES EQUATIONS FOR FLUID MOTION. The equations that describe the motion of an incompressible, New-

tonian fluid (see **fluid, Newtonian**). In tensor form, they are

$$\rho \frac{\partial u_i}{\partial t} + \rho u_j \frac{\partial u_i}{\partial x_j} = - \frac{dp}{\partial x_i} + \eta \frac{\partial^2 u_i}{\partial x_j^2}$$

where ρ is the fluid density, u_i is the component of the velocity parallel to $0x_i$, p is the pressure, η is the fluid viscosity.

NC. An abbreviation applied to tube-base diagrams to indicate no connection.

NEAR FIELD. The acoustic radiation field close to the source.

NEAR POINT OF THE EYE. The nearest point at which a small object may be seen distinctly.

NEAREST NEIGHBOR. Any atom whose distance from a given atom in a **crystal lattice** is such that no other atom is closer to the given atom. The number of nearest neighbors is the **coordination number** of the lattice

NEC. Abbreviation for National Electronics Conference.

NEEDLE. (1) The part of a **phonograph pickup** which comes into contact with the **record groove.** (2) The pointer of an electrical indicating instrument (3) The moving element of an **electrometer.**

NEEDLE CHATTER. See **needle talk.**

NEEDLE SCRATCH. The predominantly high-frequency **noise output** of a **phonograph pickup** due to the inhomogeneity of the groove surfaces of the record.

NEEDLE TALK. The direct acoustic output from a **phonograph needle** produced as it travels along a modulated groove

NEGATIVE BRANCH. See **Fortrat parabola.**

NEGATIVE CRYSTAL. A birefringent crystal in which the velocity of the extraordinary ray is greater than the velocity of the ordinary ray. (See **double refraction.**) Calcite is an example of a negative crystal.

NEGATIVE ELECTRON. A term sometimes applied to the **electron** when it is necessary to distinguish between electrons and **positrons.**

NEGATIVE FEEDBACK. See **feedback, negative.**

NEGATIVE GLOW. The luminous region in a **gas-discharge** at moderately-low pressure, as in a **Crookes tube,** between the **cathode dark space** and the **Faraday dark space.**

NEGATIVE GRID GENERATOR. Any of the various electron-tube oscillators (see **oscillator, electron-tube**) which is designed to operate without drawing **grid current** at any time during the oscillation cycle.

NEGATIVE-ION BLEMISH. See **ion burn in cathode-ray tubes.**

NEGATIVE ION VACANCY. A site in the lattice of an **ionic crystal** from which a **negative ion** is absent. Such a vacancy has an effective positive charge, since putting the negative ion back into place must render the crystal neutral.

NEGATIVE LENS SYSTEM. Another name for a **divergent lens system.**

NEGATIVE MODULATION. See **modulation, negative.**

NEGATIVE NODAL POINTS. Points which lie as far from the **focal points** as the ordinary cardinal **nodal points,** but on opposite sides Their position is such that the **angular magnification** is unity, but negative.

NEGATIVE PICTURE PHASE. The condition in a television system in which an increase in **brilliance** corresponds to an increase in the negative value of the **video signal.**

NEGATIVE PRINCIPAL POINTS. Conjugate points of a **lens** for which the **lateral magnification** is unity and negative. They lie at twice the focal length and at opposite sides of the lens.

NEGATIVE PROTON. The same as **antiproton.**

NEGATIVE - RESISTANCE OSCILLATOR. See **oscillator, negative-resistance.**

NEGATIVE TRANSMISSION. Negative modulation. (See **modulation, negative.**)

NEGATRON. (1) A term used for electron when it is necessary to distinguish between (negative) **electrons** and **positrons.** (2) A four-element **vacuum tube** which displays a negative **resistance characteristic.**

NEMA. Abbreviation for National Electric Manufacturers Association.

NEMATIC PHASE. One of the forms of the **mesomorphic state,** the "liquid crystals." The characteristic appearance is that of mobile, thread-like structures, especially visible upon examination of thick specimens with **polarized light.** This form has a single **optical axis,** which takes the direction of an applied magnetic field. The liquid appears turbid but does not yield an x-ray diffraction pattern.

NEMO. Broadcast parlance for a remote circuit.

NEODYMIUM. Rare earth metallic element. Symbol Nd. Atomic number 60

NEON. Gaseous element. Symbol Ne Atomic number 10.

NEPER (NAPIER). A unit used to express the scalar ratio of two currents or two voltages, the number of nepers being the natural logarithm of such ratio With I_1 and I_2 designating the scalar value of two currents, and N the number of nepers denoting their scalar ratio

$$N = \ln (I_1/I_2) \text{ nepers.}$$

When the conditions are such that the power ratio is the square of the corresponding current or voltage ratio, the number of nepers by which the corresponding voltages or current differ may be expressed by the following formula:

$$N = \tfrac{1}{2} \ln (P_1/P_2) \text{ nepers}$$

where P_1/P_2 is the given power ratio By extension, this relation between number of nepers and power ratio is sometimes applied where this ratio is not the square of the corresponding current or voltage ratio; to avoid confusion, such usage should be accompanied by a specific statement of this application. One neper is equal to 8 686··· **decibels.** The neper is used in mechanics and acoustics by extending the above definition to include all scalar ratios of like quantities which are analogous to current or voltage.

NEPHELOMETER. A **photometric** instrument for determining the amount of light transmitted (or scattered) by a **suspension** of particles. Since this quantity is dependent upon the size and concentration of the particles, the method provides a means of determining particle size, if the number can be determined, or particle concentration, if the size can be controlled. As used in analytical procedures, one or more of the factors are eliminated by precipitating under standard conditions, or by comparison with a standard so that the instrument can be used in quantitative determinations.

NEPHELOMETRY. The measurement of the concentration, particle size, etc , of suspension by means of its light transmission or dispersion, etc , and the application of the results, especially in chemical analysis.

NEPHOSCOPE. An instrument used in observing the direction and velocity of cloud movement.

NEPTUNIUM. Transuranic radioactive element Symbol Np. Atomic number 93.

NERNST APPROXIMATION FORMULA. A formula for the **equilibrium constant** of a gas reaction derived from the **Nernst heat theorem** by certain simplifying approximations. This formula is expressed as:

$$\log K_p = -\frac{\Delta H}{4.57T} + \Sigma\nu 1.75 \log T + \frac{\beta}{4.57} T + \Sigma\nu I$$

where K_p is the equilibrium constant of the reaction, ΔH is its change in **heat content,** $\Sigma\nu$ is the algebraic sum of the number of moles of the gaseous reactants (or in other words, the change in number of moles of gaseous reactants due to the reaction), T is the absolute temperature, β is a constant, and I is the conventional chemical constant.

NERNST BRIDGE. A four-arm bridge in which all four arms are capacitances; used for capacity measurements at high frequencies.

NERNST EFFECT. If heat is flowing through a strip of metal and the strip is placed in a magnetic field perpendicular to its plane, a difference of electric potential develops between the opposite edges. This phenomenon, discovered by Nernst in 1886, is analogous to the **Hall effect,** but with a longitudinal flow of heat replacing the longitudinal electric current. If, to one looking along the

strip in the direction of the heat flow, and with the magnetic field directed downward, the transverse potential drop is toward the right, the Nernst effect is said to be positive. (But Nernst at first used the opposite convention.) Bismuth, in which the phenomenon was first observed, shows the positive effect, iron the negative. (See also **Ettingshausen** and **Righi-Leduc effects.**)

NERNST EQUATION. An equation for electrode potential based on the concept of **electrolytic solution pressure.**

NERNST HEAT THEOREM. For a homogeneous system, the rate of change of the free energy with temperature, as well as the rate of change of heat content with temperature, approaches zero as the temperature approaches absolute zero.

NERNST LAMP. See **lamp, Nernst.**

NERNST-THOMPSON RULE. A solvent of high **dielectric constant** favors **dissociation** by reducing the electrostatic attraction between positive and negative ions, and conversely a solvent of low dielectric constant has small dissociating influence on an electrolyte.

NET PLANE. See **atomic plane.**

NET TRANSPORT. The difference between the total rate at which desired **isotopes** are transmitted toward the production end of a separation plant through any section, and the rate at which they would be carried in the same flow by material of natural abundance.

NETWORK. A combination of **network elements.**

NETWORK, ALL-PASS. A **network** designed to introduce **phase shift** or delay without introducing appreciable **attenuation** at any frequency.

NETWORK ARM. A portion of a **network** consisting of one or more two-terminal elements in series.

NETWORK, ACTIVE. A **network** whose output waves are dependent upon sources of power, apart from that supplied by any of the actuating waves which power is controlled by one or more of these waves.

NETWORK BRANCH. See **network arm.**

NETWORK BRANCH, IMPEDANCE OF. See **impedance of network branch.**

NETWORK, BRIDGED-T. A T network (see **network, T**) with a fourth branch connected across the two series arms of the T, between an input terminal and an output terminal.

NETWORK, CONNECTED. A **network** in which there exists at least one path, composed of **branches** of the network, between every pair of **nodes** of the network.

NETWORK, CUT-SET. A set of **branches** of a **network** such that the cutting of all the branches of the set increases the number of separate parts of the network, but the cutting of all the branches except one does not.

NETWORK, DE-EMPHASIS. A **network** inserted in a system in order to restore the **pre-emphasized** frequency spectrum to its original form.

NETWORK, DELTA. A set of three **branches** connected in series to form a **mesh.**

NETWORK, DIFFERENTIATING. A **network** whose output is the time derivative of its input wave form. Such a network preceding a frequency **modulator** makes the combination a phase modulator; or, following a phase detector, it makes the combination a frequency **detector.** Its ratio of output amplitude to input amplitude is proportional to frequency, and its output phase leads its input phase by 90°.

NETWORK, DISSYMMETRICAL. A network which is not structurally symmetrical. (See **network, structurally symmetrical.**)

NETWORK, DIVIDING (LOUDSPEAKER DIVIDING NETWORK). A frequency-selective **network** which divides the spectrum to be radiated into two or more parts.

NETWORK, DUAL. See **network, structurally-dual.**

NETWORK, ELECTRIC. A combination of elements, either as a combination of interconnected devices (such as **inductors, capacitors, resistors, generators,** etc.), or as the abstraction of interconnected branches having the properties of **inductance, resistance, capacitance,** etc. (See **alternating-current circuit; Kirchhoff laws.**)

NETWORK ELEMENT. Any electrical device (such as inductor, resistor, capacitor, generator, line, electron tube) with terminals at which it may be directly connected to other electrical devices.

NETWORK, EQUIVALENT. A network which, under certain conditions of use, may replace another network. The networks need not be of the same form; for example, one may be mechanical, the other electric. If one network can replace another network in any system whatsoever without altering in any way the operation of that portion of the system external to the networks, the networks are said to be "networks of general equivalence." If one network can replace another network only in some particular system without altering in any way the operation of that portion of the system external to the networks, the networks are said to be "networks of limited equivalence." Examples of the latter are networks which are equivalent only at a single frequency, over a single band, in one direction only, or only with certain terminal conditions (such as H and T networks).

NETWORK, Π. A network composed of five branches, two connected in series between an input terminal and an output terminal, two connected in series between another input terminal and a second output terminal, and the fifth connected from the **junction point** of the first two branches to the junction point of the second two branches.

NETWORK, INTEGRATING. A **network** whose output wave form is the time integral of its input wave form. Such a network preceding a **phase modulator** makes the combination a **frequency modulator**; or, following a **frequency detector,** makes the combination a **phase detector.** Its ratio of output amplitude to input amplitude is inversely proportional to frequency, and its output phase lags its input phase by 90°.

NETWORK, L. A network composed of two **branches** in series, the free ends being connected to one pair of terminals, and the **junction point** and one free end being connected to another pair of terminals.

NETWORK, LADDER. A **network** composed of a sequence of H, L, T, or Π networks connected in tandem.

NETWORK, LATTICE. A **network** composed of four branches connected in series to form a **mesh,** two nonadjacent **junction points** serving as input terminals, while the remaining two junction points serve as output terminals.

NETWORK, LINEAR. A network for which the pertinent measures of all the waves concerned are linearly related. By "linearly related" is meant any relation of linear character, whether linear algebraic equation or linear differential equation or other linear connection. The term "waves concerned" connotes actuating waves and related output waves, the relation which is of primary interest in the problem at hand.

NETWORK, LINEAR PASSIVE ELECTRIC. A **network** whose state is described by a number of independent voltages, or a number of independent currents. The voltages are linear functions of the currents (and conversely).

NETWORK MESH. A set of **branches** forming a closed path in a **network,** provided that if any one branch is omitted from the set, the remaining branches of the set do not form a closed path. The term loop is sometimes used in the sense of mesh.

NETWORK, NODE (JUNCTION POINT), (BRANCH POINT), (VERTEX). A terminal of any **branch** of a **network** or a terminal common to two or more branches of a network.

NETWORK, NONLINEAR. A **network** (circuit) not specifiable by linear differential equations with time as the independent variable.

NETWORK, NONPLANAR. A **network** which cannot be drawn on a plane without crossing of **branches.**

NETWORK, *N*-TERMINAL. A network with N accessible terminals.

NETWORK, *N*-TERMINAL PAIR. A network with 2 N accessible terminals grouped in pairs. In such a network one terminal of each pair may coincide with a **network node.**

NETWORK, PASSIVE. A **network** whose output waves are independent of any sources of power which is controlled by the actuating waves.

NETWORK, PI. A **network** composed of three branches connected in series with each other to form a **mesh,** the three **junction points** forming an input terminal, an output terminal, and a common input and output terminal, respectively.

NETWORK, PLANAR. A **network** which can be drawn on a plane without crossing of branches.

NETWORK, PRE-EMPHASIS. A **network** inserted in a system in order to emphasize one range of frequencies with respect to another.

NETWORK, QUADRIPOLE. See **network, two-terminal pair.**

NETWORK, SERIES TWO-TERMINAL PAIR. Two-terminal pair networks are connected in series at the input or at the output terminals when their respective input or output terminals are in series.

NETWORK, STAR. A **set** of three or more **branches** with one terminal of each connected at a common **node.**

NETWORKS, STRUCTURALLY-DUAL. A pair of **networks** such that their branches can be marked in one-to-one correspondence so that any **mesh** of one corresponds to a **cut-set** of the other. Each network of such a pair is said to be the dual of the other.

NETWORK, STRUCTURALLY SYMMETRICAL. A **network** which can be arranged so that a cut through the network produces two parts that are mirror images of each other.

NETWORK, SYMMETRICAL. See **network, structurally symmetrical.**

NETWORK, T. A **network** composed of three **branches** with one end of each branch connected to a common **junction point,** and with the three remaining ends connected to an input terminal, an output terminal, and a common input and output terminal, respectively.

NETWORK, TWO-TERMINAL PAIR (QUADRIPOLE) (FOUR-POLE). A **network** with four accessible terminals grouped in pairs. In such a network, one terminal of each pair may coincide with a network **node.**

NETWORK, Y. A star network (see **network, star**) of three branches.

NEUMAN PRINCIPLE. The physical properties of a crystal cannot be of lower symmetry than the symmetry of the external form of the crystal. Thus, for example, all the properties of a cubic crystal must have cubic symmetry—which means that any tensor property such as susceptibility, resistivity, thermal expansion, etc., must be **isotropic.**

NEUMANN BOUNDARY CONDITIONS. Specification of the normal derivative of the solution to a **partial differential equation** along a bounding curve.

NEUMANN FUNCTION. Also called a Bessel function of the second kind, it is defined by

$$N_n(x) = \csc n\pi[\cos n\pi J_n(x) - J_{-n}(x)]$$

where $J_n(x)$ is a **Bessel function.** The general solution of the **Bessel differential equation** can be taken as $y = AJ_n(x) + BN_n(x)$, where A, B are integration constants. The index n may be either non-integral or integral but in the latter case $N_n(x)$ contains a logarithmic term so that this solution is usually unsuitable for a physical problem because of its behavior at $x = 0$.

NEUTRAL. (1) Having no electric charge, or no net electric charge. (Thus, an atom, in which the total negative charge of the electrons is equal to the positive change of the nucleus which they surround, is a neutral atom.) (2) According to the ionization hypothesis, a concentration of hydrogen ions equal to 1×10^{-7}. (The figure varies a little according to the temperature and the method of determining the degree of ionization of water.) Hydrogen-ion concentrations greater than this figure confer acid properties; lower concentrations occur in alkaline systems.

NEUTRAL ATOM. An atom in which the positive charge on the nucleus is equal to the total negative charge of the electrons which surround the nucleus. Therefore, the atom does not possess an electric charge.

NEUTRAL DENSITY FILTER. A light **filter** which reduces the intensity of the light without changing the relative spectral distribution of the energy. Also called gray filters. Few absorption-type filters are absolutely neutral.

NEUTRAL MOLECULE. In general, a molecule without electrical charge; the term is applied often to a system of two ions of opposite but equal charge, in a solvent. The two ions comprising this system differ from solvated ions, which consist of complexes formed between molecules of solvent and ions.

NEUTRAL POINT. In meteorology, any point at which the axis of a wedge of high pressure intersects the axis of a trough of low pressure. Also called "saddle point."

NEUTRALIZATION. A method of nullifying the voltage **feedback** from the output to the input circuits of an **amplifier** through the tube interelectrode impedances. Its principal use is in preventing oscillation in an amplifier by introducing a voltage into the input, equal in magnitude but opposite in phase to the feedback through the **interelectrode capacitance.**

NEUTRALIZATION, CROSS. A method of **neutralization** used in **push-pull amplifiers** whereby a portion of the plate-cathode alternating-current voltage of each tube is applied to the grid-cathode circuit of the other tube through a neutralizing capacitor.

NEUTRALIZATION, INDUCTIVE (SHUNT, COIL). A method of neutralizing an **amplifier** whereby the **feedback susceptance** due to the plate-to-grid capacitance is cancelled by the equal and opposite susceptance of an **inductor.**

NEUTRALIZATION, PLATE. The method of neutralizing an **amplifier** in which a portion of the plate-cathode alternating-current voltage is shifted 180°, and applied to the grid-cathode circuit through a neutralizing capacitor.

NEUTRALIZING INDICATOR. An auxiliary device for indicating the degree of **neutralization** of an **amplifier.** (For example, a lamp or detector coupled to the plate-tank circuit of an amplifier.)

NEUTRALIZING POWER OF A LENS. The reciprocal of **front focal length.**

NEUTRALIZING VOLTAGE. The alternating-current voltage specifically fed from the **grid circuit** to the plate circuits (or vice versa), deliberately made 180° out of phase with and equal in amplitude to the alternating-current voltage similarly transferred through undesired paths, usually the grid-to-plate tube capacitance.

NEUTRINO. A neutral particle of very small (possibly zero) rest mass and of spin quantum number ½. The mass has been shown experimentally to be less than $0.01m_e$. This particle was postulated to account for the continuous energy distribution of β-particles and to conserve angular momentum in the **β-decay process.** Experimental evidence is also accumulating to the effect that, for the linear momentum to be conserved in the β-process, there must be a contribution from a departing neutrino. Presumably, a neutrino (or antineutrino) is emitted in every β-transition. The energy of a neutrino emitted in a β-disintegration is assumed to be equal to the difference between the energy of the particular β-particle and the energy corresponding to the upper limit of the continuous spectrum for that β-transition. The neutrino has also been postulated as one of the particles in π-meson decay and as one or two of the particles in μ-meson decay. Because of its properties, the neutrino has very weak interactions with matter. The symbol ν is often used for the neutrino.

NEUTRINO THEORY OF LIGHT. Theory in which a photon is described in terms of a transition of a **neutrino** from one state to another, the direction of motion of the neutrino being unchanged in the process. The theory of the interaction of such a photon with an atom then leads to a condition which is inconsistent with the **commutation rules.**

NEUTRODYNE. An **amplifier stage** neutralized with voltage fed back through **a capacitor.** Old usage.

NEUTRON. A neutral elementary particle of mass number 1. It is believed to be a constituent particle of all nuclei of mass number greater than 1. It is unstable with respect to β-decay, with a half-life of about 12 min. It produces no detectable primary ionization in its passage through matter, but interacts with matter predominantly by collisions and, to a lesser extent, magnetically. Some properties of the neutron are: rest mass, 1.00894 atomic mass unit; charge, 0; spin quantum number, ½; magnetic **moment,** −1.9125 nuclear Bohr **magnetons;** statistics, **Fermi-Dirac.**

NEUTRON CONSERVATION OR BALANCE. The underlying principle for any theory of nuclear **reactors.** It may be stated as follows: In a given volume, the time rate of change of neutron density is equal to the rate of production minus the rate of leakage and the rate of absorption.

NEUTRON CRYSTAL SPECTROMETER, VELOCITY-SELECTOR. A device in which slow neutrons from an intense source are allowed to impinge on a crystal, and a detector is placed so that the diffracted beam falls upon it. For any arbitrarily chosen value of the glancing angle θ, the great majority of neutrons reaching the detector will have a velocity given by the Bragg equation:

$$v = \frac{nh}{2dm \sin \theta}$$

where n is an integer, usually unity, h is the Planck constant, d is the crystal spacing, and m is the mass of the neutron

NEUTRON CURRENT DENSITY. The number of neutrons crossing unit surface per unit time, in a direction normal to the surface.

NEUTRON CYCLE. The life history of the neutrons in a nuclear **reactor** starting with the fission process and continued until all the neutrons have been absorbed or have leaked out.

NEUTRON DENSITY. The number of neutrons per unit volume. Partial densities may be defined for neutrons characterized by such parameters as speed and direction.

NEUTRON DETECTION. Neutrons may be detected by making use of the charged particles produced by the interaction of neutrons with atomic nuclei, as in the boron-trifluoride **counter,** or by observing charged particle recoils resulting from the collision of the neutrons with protons, etc.

NEUTRON ENERGY, FAST NEUTRON REGION OF. The energy region above about 10 ev.

NEUTRON ENERGY, RESONANCE REGION OF. The energy region from about 0.1 ev to about 10 ev, characterized in many substances by the occurrence of peaks where the absorption cross section (see **cross section, absorption**) rises to high values for certain neutron energies, and then falls again.

NEUTRON EXCESS. The difference between the number of neutrons and the number of protons in the nucleus; found by subtracting the **atomic number** of that nuclide from the **neutron number;** or by subtracting twice the atomic number from the **mass number.**

NEUTRON FISSION-SCINTILLATION APPARATUS. A device for the detection of slow neutrons in which a small amount of a uranium compound enriched in fissionable U^{235} is mixed with a substance capable of producing luminescence when struck by a fission fragment. The luminescence is then detected by a scintillation counter. (See **counter, scintillation.**)

NEUTRON FLUX. For neutrons of a given energy, the product of neutron density with speed. (See **flux.**)

NEUTRON FORMATION BY STRIPPING. If a high energy deuteron strikes a target nucleus in such a way as to graze the edge of the latter, the proton (in the deuteron) may be stripped off, while the neutron continues to travel in a straight line.

NEUTRON HARDENING. The effect caused by the diffusion of thermal neutrons through a medium having an absorption **cross section** decreasing with energy Because the slower neutrons are preferentially absorbed, the average energy of the diffusing neutrons becomes greater.

NEUTRON HOWITZER. A collimating apparatus for the production of a stream of **neutrons,** consisting of a source of neutrons, such as a mixture of beryllium filings and radon, contained in a block of paraffin, from which the stream of neutrons escapes by a circular passage, small in cross-sectional area and lined with cadmium.

NEUTRON LEAKAGE. The loss of neutrons from a nuclear **reactor** due to leakage through the boundaries of the reactor.

NEUTRON MAGNETIC MOMENT. The neutron magnetic moment is equal in magnitude to 1 913 **Bohr** nuclear **magnetons.** The direction of the moment is opposite to that of the proton.

NEUTRON NUMBER. The number of neutrons in a **nucleus.** Its symbol is N, and it is

indicated symbolically when desired by a subscript number *following* the symbol of the nuclide. The neutron number for a given nuclide is equal to the difference between the mass number for that nuclide and the atomic number.

NEUTRON PRODUCER. A nuclear **reactor** designed as a source of neutrons for isotope production.

NEUTRON - PROTON EXCHANGE FORCES. Forces postulated in an attempt to explain nuclear forces in terms of an energy contribution brought about quantum-mechanically as the result of the exchange of charge between a proton and a neutron.

NEUTRON RADIATIVE CAPTURE. The capture of a slow neutron by an atomic nucleus with the prompt emission of one or more γ-rays, the total energy of which is equal to the **binding energy** of the neutron in the compound nucleus.

NEUTRON REFLECTION. Neutrons may be reflected by crystalline materials according to the **Bragg law** for the **de Broglie wavelength** characteristic of their energy, or they may be totally reflected by highly polished surfaces of selected materials at angles smaller than their **critical angle.**

NEUTRON VELOCITY SELECTOR. Any of several types of instruments in which neutrons of a particular velocity or range of velocities are singled out for detection. In the simplest type, cadmium is used to shield the detector. Neutrons of energy less than about 0.3 ev are strongly absorbed in the cadmium and are therefore not detected. In the time-of-flight selector neutrons are detected which take a given time to traverse a fixed distance. The neutron crystal velocity selector makes use of the **Bragg diffraction** of neutrons from a crystal.

NEUTRONS, DELAYED. Neutrons emitted by excited nuclei formed in a radioactive process (β-disintegration, in all cases so far known). The neutron emission itself is prompt, so that the observed half-life is that of the preceding β-emitter. The situation is similar to that involving γ-ray emission, which is a competing process. Delayed neutron emission is possible only if the excitation energy of the product nucleus exceeds the **neutron binding energy** for that nucleus. The chemistry of the delayed neutron emitter is that of the β-activity; thus Br^{87}, I^{137} and N^{17} are delayed neutron precursors, although the neutron emission actually takes place from excited nuclei of the products Kr^{87}, Xe^{137} and O^{17}.

NEUTRONS, EPITHERMAL. Neutrons having energies just above those of thermal neutrons; the epithermal neutrons' energy range is between a few hundredths ev and about 100 ev.

NEUTRONS, FAST. Neutrons with energies exceeding 10^5 ev, although sometimes a lower limit is given.

NEUTRONS, INTERMEDIATE. Neutrons having energies in a range that extends roughly from 100 to 100,000 ev. This range is above that of **epithermal neutrons** and below that of **fast neutrons.**

NEUTRONS, RESONANCE. (1) For a specified nuclide or element, **neutrons** that have energies in the region where the cross section of the nuclide or element is particularly large because of the occurrence of a resonance. For example, cadmium resonance neutrons have energies between 0.05 and about 0.3 ev. (2) Neutrons having kinetic energies in the region of values for which prominent resonances are encountered in many nuclides: loosely, epithermal neutrons.

NEUTRONS, SLOW. (1) Neutrons having kinetic energies up to about 10^2 ev. (2) Loosely used as a synonym for **thermal neutrons.** (See **neutrons, thermal.**)

NEUTRONS, SOURCES OF. Neutrons may be produced as the result of nuclear transformations such as (α,n), (γ,n), (p,n), or (d,n), or they may be produced in nuclear **reactors** as a result of fission. In each of these processes fast neutrons are produced; in order to get slow neutrons, a moderator such as paraffin must be used to slow the neutrons down

NEUTRONS, SOURCES OF MONOENERGETIC. See **neutron velocity selector.**

NEUTRONS, THERMAL. Neutrons in thermal equilibrium with the substance in which they exist; commonly, neutrons of **kinetic energy** about 0.025 ev, which is about ⅔ of the mean kinetic energy of a molecule at 15°C.

NEWTON. A unit of force in the **MKS system,** abbreviation new or N. The force necessary to impart an acceleration of one meter per second per second to a mass of one kilogram.

NEWTON-COTES FORMULA. A method of **numerical integration.** Assume that the integral

$$\int_a^b f(x)dx$$

may be approximated by

$$\int_a^b \phi(x)dx = A_0y_0 + A_1y_1 + \cdots + A_ny_n$$

where the quantities A_i are independent of y_i. By proper choice of these quantities, the numerical result may be made very close to the true value of the integral. Special cases of the formula are the **trapezoidal rule,** the **Simpson rule,** and the **Weddle rule.**

NEWTON EMISSION THEORY. The hypothesis advanced by Sir Isaac Newton that light was due to an emission of luminous corpuscles from a source.

NEWTON FORMULA FOR INTERPOLATION. Let a **difference table** be given with numerical values of $y_0, y_1, y_2 \cdots$; equally spaced values of the argument, $x_0, x_1, x_2 \cdots$; $h = (x_n - x_0)/n$ and the **finite differences,** $\Delta^n y_k$. Then a value of y for $x = x_k + hu$, not contained in the table, may be found by Newton's formula for forward interpolation

$$y = y_k + u\Delta y_k + \binom{u}{2}\Delta^2 y_k + \cdots + \binom{u}{n}\Delta^n y_k.$$

As its name implies, this equation is used for calculation near the beginning of a difference table. Near the end of such a table, Newton's formula for backward interpolation is appropriate.

$$y = y_k - v\Delta y_{k-1} + \binom{v}{2}\Delta^2 y_{k-2} \pm \cdots + (-1)^n \binom{v}{n}\Delta^k y_0$$

where $x = x_k - hv$. These equations are also known as **Gregory-Newton formulae.**

NEWTON LAW FOR HEAT LOSS (COOLING). The heat lost by radiation and convection from one body to another is proportional to the temperature difference between the two bodies. This law holds only for small temperature differences and then only approximately.

NEWTON LAW OF HYDRODYNAMIC RESISTANCE. The force opposing the steady motion of a solid body through a fluid medium is proportional to the square of the velocity, the density of the fluid and the cross-sectional area of the body. This law is approximately true for bluff bodies (spheres, flat plates, etc.), but is seriously in error for streamlined bodies.

NEWTON LAW OF UNIVERSAL GRAVITATION. Every particle in the universe attracts every other particle with a force that is directly proportional to the product of their masses, and inversely proportional to the square of the distance between their centers of mass. The constant of proportionality in the c.g.s. system of units is

$$G = 6.670 \times 10^{-8}\,\frac{\text{dyne cm}^2}{\text{g}^2}.$$

(See **Newton theory of gravitation.**)

NEWTON LAWS OF MOTION. (1) A particle remains at rest or in a state of uniform motion in a straight line unless acted upon by an external force. (2) The acceleration produced by a force is directly proportional to the force and inversely proportional to the mass of the particle which is being accelerated. (3) To every action there is an equal and opposite reaction.

Newton's laws of motion may be considered as the basic postulates of the theory of mechanics. They apply strictly only to infinitesimal particles, but may be extended to rigid bodies by the assumption that these bodies may be treated as collections of particles. They are also limited to instances in which classical mechanics apply, i.e., to cases in which the speeds of motion are small compared to the speed of light.

NEWTON METHOD FOR SOLUTION OF EQUATIONS. Let $x = x_0$ be a first approximation to a real root of an equation $f(x) = 0$ found by trial, by graph or otherwise. Then a second approximation to the root is given by the formula

$$x = x_0 - \frac{f(x_0)}{f'(x_0)}$$

where f' is the derivative of f. A new approximation may be obtained by substituting in this formula again and so on until the desired degree of accuracy is obtained. The formula is based on finding the point where the tangent to the curve at $x = x_0$ cuts the X-axis. Sometimes also called the Newton-Raphson method.

NEWTON RINGS. An **interference** phenomenon, easily observed by laying a slightly convex lens upon a flat glass plate. When the lens and plate are arranged so that monochromatic light is reflected at a suitable angle to the observer's eye, the point of contact is seen to be surrounded by a series of concentric, alternately bright and dark rings, which become closer together with increasing radius. The rings are due to the interference of light at the film of air between the glass surfaces, which film increases in thickness with increasing distance from the contact point

NEWTON THEORY OF GRAVITATION. Newton's conception of gravitation was expressed by his statement. to the effect that every particle of matter attracts every other particle with a force proportional to the product of the masses and to the inverse square of the distance We are thus left to picture an infinitely complex network of attractions joining every two particles in the universe and tending to pull them together Newton did not specify what the "particles' were assumed to be, whether atoms or otherwise.

The Newtonian law may be expressed by the equation $f = Gm_1m_2/r^2$, in which m_1 and m_2 are the masses of two particles, r the distance between them, and G the gravitation constant. For practical purposes the "particles" may be homogeneous spheres, r being the distance between their centers. Other bodies of finite size, such as cubes or cylinders, would not do, as they are not "centrobaric"; that is, there is no one point toward which their attraction is directed The planets and stars, being sensibly spherical, may be treated approximately as particles It was from the study of the two-body problem as applied to such objects that Newton deduced the conclusion expressed in his law.

NEWTONIAN FLUID. See **fluid, Newtonian.**

NEWTONIAN POTENTIAL FUNCTION. See **potential.**

NEWTONIAN TELESCOPE. A reflecting-type telescope with a 45° mirror, so that the primary image is observed through a hole in the side of the tube.

NICALOI. A high-permeability, isotropic magnetic alloy composed of approximately 50% nickel, 50% iron.

NICHOLS RADIOMETER. The apparatus used by Nichols and Hull for the measurement of **radiation pressure** (1901) consisted of a pair of small, silvered glass mirrors suspended, in the manner of a **torsion balance,** by a fine quartz fiber within an enclosure in which the air pressure could be regulated. The torsion head to which the fiber was attached could be turned from outside the enclosure by means of a magnet. A beam of light was directed first on one mirror and then on the other, and the opposite deflections observed with mirror and scale. By turning the mirror system around so as to receive the light on the unsilvered side, the influence of the air in the enclosure could be ascertained. This influence was found to be a minimum, and to have an almost negligible value, at an air pressure of about 16 mm of mercury. The radiant energy of the incident beam was deduced from its heating effect upon a small, blackened silver disk, which was found more reliable than the **bolometer** at first used. With this apparatus the experimenters were able to obtain an agreement between observed and computed radiation pressures within about 0.6 of 1%.

NICKEL. Metallic element. Symbol Ni. Atomic number 28.

NICOL PRISM. See **prism, Nicol.**

NIGHT BLINDNESS. If the **fovea** has no rods, that part of the retina **suffers** from night blindness, a term describing various degrees of inability to see with low illumination.

NIGHT EFFECTS. The errors in **bearings** taken by radio **direction-finders** caused by polarization effects in the atmosphere, usually at night.

NIGHT ERROR. See **night effects.**

NILPOTENT. An **operator,** generally represented in **matrix** form, which satisfies the relation

$$\mathbf{A}^n = 0$$

for some value of n. (See also **idempotent.**)

NIMBOSTRATUS. Type of **stratus** from which rain or snow appears to fall. Sometimes the stratus layer is merged with **altostratus** or **altocumulus**, and the total cloud layer is very deep. More frequently there is a clear break between the two layers. Nimbostratus is dull and grayish and usually ragged.

NIOBIUM. Metallic element. Symbol Nb. Atomic number 41.

NIPKOW DISK. The early **scanning disk** of mechanical **television.**

NIT. A unit of **luminance**, equal to 1 **candle**/sq m.

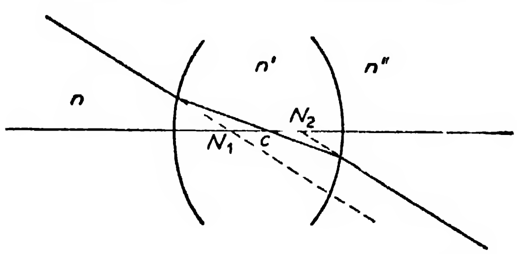
NOBLE GASES. Any of the elements He, Ne, A, Kr, Xe, Rn characterized by closed shells or subshells of electrons. So-called because of their chemical inactivity.

NOCTOVISION. A television system for seeing in the dark, usually employing **infrared** rays.

NODAL LINES. On a vibrating diaphragm, lines along which no vibration takes place If the diaphragm is circular they consist of two kinds, concentric nodal circles and nodal diameters.

NODAL PLANE. See discussion of **nodal points.**

NODAL POINT(S). (1) Of all the rays that pass through a lens from an off-axis object point to its corresponding image point, there will always be one for which the direction of the ray in the image space is the same as that in the object space. The two points at which



these segments, if projected, intersect the axis are called the nodal points, and the transverse planes through them are called the nodal planes. Only if n and n'', the indices of refraction in the object and image spaces, are identical are the nodal planes also the principal planes. C is the optical center of the lens. (2) For uses of this term in electromagnetics, acoustics and mathematics, see **node(s).**

NODAL POINT KEYING. Keying a spark transmitter at an **antenna node** or minimum voltage point.

NODAL SLIDE. Essentially a small optical bench on which a lens system may be mounted and which may be rotated about a vertical axis. Useful in the experimental determination of the cardinal points of a compound **lens.**

NODE(S). (1) The points, lines, or surfaces in a standing wave system (see **wave, standing**) where some characteristic of the wave field has essentially zero amplitude. The appropriate modifier should be used with the word "node" to signify the type that is intended (pressure node, velocity node, etc). (See also **loop.**) (2) A terminal of any **branch** of a **network**, or a terminal common to two or more branches of a network The terms junction point, branch point, and vertex may be used instead of node in this connotation. (3) A singular point on a curve having the property that two branches of the curve, with distinct tangents, pass through the point. Also called a **crunode.**

NODE(S), PARTIAL. The points, lines, or surfaces in a standing wave system (see **wave, standing**) where some characteristic of the wave field has a minimum amplitude differing from zero The appropriate modifier should be used with the words "partial node" to signify the type that is intended (pressure partial node, velocity partial node, etc.).

NODON VALVE. An **electrolytic rectifier** with a lead anode and an aluminum cathode. The electrolyte is ammonium phosphate.

NOISE. Any undesired sound. By extension, noise is any unwanted disturbance within a useful frequency band, such as undesired electric waves in any transmission channel or device. Such disturbances, when produced by other services, are called **interference.**

NOISE, BACKGROUND. (1) **Noise** due to audible disturbances of periodic and/or random occurrence. (2) In receivers, the noise in absence of **signal modulation** on the **carrier.** (3) In recording and reproducing, background noise is the total system noise independent of whether or not a signal is **present. The**

signal should not be included as part of the noise.

NOISE BEHIND THE SIGNAL. See **noise, modulation.**

NOISE "CLICK." See **noise, impulse.**

NOISE, ELECTRICAL. Unwanted electrical energy, other than **cross talk,** present in a transmission system or in a measuring device. For the sources and nature of such noise, see **noise, shot; noise, thermal.**

NOISE FACTOR (NOISE FIGURE). Of a linear system at a selected input frequency, the ratio of (1) the total **noise power** per unit **bandwidth** (at a corresponding output frequency) available at the output terminals, to (2) the portion thereof engendered at the input frequency by the input termination, whose **noise temperature** is standard (290°K) at all frequencies For heterodyne systems there will be, in principle, more than one output frequency corresponding to a single input frequency, and vice versa; for each pair of corresponding frequencies a noise factor is defined. The phrase, "available at the output terminals," may be replaced by "delivered by the system into an output termination," without changing the sense of the definition.

NOISE FACTOR (NOISE FIGURE), AVERAGE. Of a linear system, the ratio of (1) the total noise power delivered by the system into its output termination when the **noise temperature** of its input termination is standard (290°K) at all frequencies to (2) the portion thereof engendered by the input termination For heterodyne systems, portion (2) includes only that noise from the input termination which appears in the output via the principal frequency transformation of the system and does not include spurious contributions such as those from image-frequency transformations. A quantitative relation between average noise factor, $\bar{F}$, and spot noise factor, $F(f)$, is

$$\bar{F} = \frac{\int_0^\infty F(f)G(f)df}{\int_0^\infty G(f)df},$$

where f is the input frequency and $G(f)$ is the ratio of (a) the signal power delivered by the system into its output termination to (b) the corresponding signal power available from the input termination at the input frequency. For heterodyne systems, (a) comprises only power appearing in the output via the principal frequency transformation of the system; in other works, power via image-frequency transformations is excluded.

NOISE FACTOR (NOISE FIGURE) SPOT. A term used where it is desired to emphasize that the **noise factor** is a point function of input frequency.

NOISE FIGURE. See **noise factor.**

NOISE FILTER. A **filter** inserted between the power source and electronic equipment to prevent the entry of unwanted frequencies.

NOISE, FLICKER. A **noise** caused by random variations in the activity of emitting surfaces of cathodes in electron tubes The flicker noise power varies as an inverse function of frequency.

NOISE, GROUND. In recording and reproducing, the residual system noise in the absence of the signal. It is usually caused by inhomogeneity in the recording and reproducing media, but may also include amplifier noise such as tube noise or noise generated in resistive elements in the input of the reproducer amplifier system.

NOISE, IMPULSE. Noise characterized by transient disturbances separated in time by quiescent intervals. The **frequency spectrum** of these disturbances must be substantially uniform over the useful **pass band** of the transmission system.

NOISE LEVEL. The value of noise integrated over a specified frequency range with a specified frequency weighting and integration time. It is expressed in decibels relative to a specified reference.

NOISE LEVEL, AMPLITUDE-MODULATION. The noise level produced by undesired amplitude variations of a radio-frequency signal in the absence of any intended **modulation.**

NOISE LEVEL, CARRIER (RESIDUAL MODULATION). The **noise level** produced by undesired variations of a radio-frequency signal in the absence of any intended **modulation.**

NOISE LIMITER. A clipper circuit (see **circuit, clipper**) which tends to reduce the interference caused by impulse noise (see **noise, impulse**) by limiting the peak voltage excursion to a value only slightly greater than that of the signal.

NOISE, MODULATION (NOISE BEHIND THE SIGNAL). The **noise** caused by the **signal.** The signal is not to be included as part of the noise. The term is used where the **noise level** is a function of the strength of the signal.

NOISE, "PARTITION." In **traveling-wave tubes** and **electron-wave tubes**, the noise which arises from progressive capture of the electrons in the beam by the wave-guiding device, whether it be a helix or some other type of structure.

NOISE "POP." See **noise, impulse.**

NOISE POWER, AVAILABLE. The maximum noise power that may be drawn from a **network** by a **load** whose impedance is the complex conjugate of the impedance of the network itself.

NOISE, RANDOM (OR FLUCTUATION). **Noise** characterized by a large number of overlapping transient disturbances occurring at random

NOISE RATIO (NR). The ratio of the available noise power (see **noise power, available**) at the output of a **transducer** divided by the noise power at the input.

NOISE REDUCTION. In photographic recording and reproducing, a process whereby the average transmission of the **sound track** of the print (averaged across the track) is decreased for signals of low level and increased for signals of high level.

NOISE, RESISTANCE. See **noise, thermal.**

NOISE SILENCER. See **noise limiter.**

NOISE, SHOT. Noise resulting from the random nature of the emission and flow of electrons in **electron tubes.**

NOISE SUPPRESSOR. A vacuum-tube circuit designed to suppress undesirable noise in a radio **receiver.** Suppressors are of two types, interchannel noise suppressors and large signal suppressors. The first acts as an **automatic volume control** to cut off the audio **amplifier** when no **carrier** is being received. The second is a peak limiting circuit to suppress all signals above a certain amplitude.

NOISE SUPPRESSOR, DYNAMIC. Essentially a **filter** for an audio system whose **band-pass** is adjusted according to the **signal level.** At low levels where noise is particularly noticeable and, at the same time, sensitivity of the ear is decreased at either end of the hearing range, the filter action decreases both the high and low (or high only) frequency response of the system; at high levels all filtering action is removed.

NOISE TEMPERATURE. At a pair of terminals and at a specific frequency, the temperature of a passive system having an available noise power per unit **bandwidth** equal to that of the actual terminals.

NOISE TEMPERATURE (STANDARD). The standard reference temperature T_0 for noise measurements is taken as 290 degrees K. $kT_0/e - 0\,0250$ volt, where e is the electron charge and k is the **Boltzmann constant.**

NOISE, THERMAL (JOHNSON NOISE). The **noise** produced by thermal agitation of charges in a conductor. The **available** thermal **noise power** produced in a resistance is independent of the resistance value, and is proportional to the absolute temperature and the frequency bandwidth over which the noise is measured, as indicated by the formula:

$$N_t = 1.38 \times 10^{-23} T \Delta F$$

in which N_t is the available thermal noise power, T is the temperature of the resistance in degrees Kelvin, and Δf is the bandwidth in cycles per second.

NOISE VOLTAGE. Spontaneous fluctuations in voltage in a physical system, such as a **semiconducting** filament.

NOISE, WHITE. Noise which contains components of all audible frequencies.

NOMINAL LINE WIDTH. See **line width, nominal.**

NOMOGRAPH. Also called an **alignment chart** or **isopleth.** It consists of two or more graphical scales, drawn and arranged so that results of calculations may be found quickly from the relation of points upon them. For example, three-scale charts of this type are

usually constructed so that in a relationship involving three variables, the value in one variable is determined by a given set of values of the other two and may be found by locating the given values of the two known variables upon their proper scales, laying a straightedge on the three scales, so that its edge cuts the two points, then the point at which it cuts the third scale is the value sought.

NON-ADIABATIC APPROXIMATION. See **Tamm-Dancoff method.**

NONCENTRAL FORCES, NUCLEAR. See **nuclear forces.**

NON-CROSSING RULE. For an infinitely slow change of internuclear distance two electronic states of the same species (i.e., states with the same Λ and the same symmetry properties) cannot cross each other. In other words, the potential energy curves of two electronic states cannot cross each other.

NONDIRECTIONAL MICROPHONE. See **microphone, omnidirectional.**

NON - EQUILIBRIUM THERMODYNAMICS. The study of the thermodynamic relations in **open systems** in the **steady state,** i.e., the time-invariant state, in which all macroscopic quantities remain unchanged, although dissipative processes may occur. Also referred to as "thermodynamics of the steady state" and "irreversible thermodynamics."

NONEX. A type of glass used where ultraviolet transmission characteristics are important.

NONION. See **dyadic.**

NON-INDUCTIVE RESISTOR. A resistor constructed in such a manner that the inductive effects are reduced to a minimum. Such construction is often required for high-frequency work.

NONLINEAR DISTORTION. See **distortion, nonlinear.**

NONLINEAR NETWORK. See **network, nonlinear.**

NONLINEARITY OF THE EAR. When a pure tone of suitable intensity is impressed upon the ear, a series of harmonics or overtones of the original frequency are heard. When two loud tones are sounded together, sum and difference frequencies are heard.

NONLOCAL FIELD THEORY. See **field theory, nonlocal.**

NONLOCALIZED MOLECULAR ORBITALS. **Molecular orbitals** not localized between two nuclei but spread over a larger part of a molecule, as around a benzene ring.

NON-METAL. An element which is not a **metal.** The distinction between metals and non-metals is not sharp; it is often safer to refer to a "metallic structure," or a "nonmetallic structure," e.g., in the case of tin, which may take either form.

NONPLANAR NETWORK. See **network, nonplanar.**

NON-RELATIVISTIC. Moving with relative velocity small compared with that of light as, for example, the nucleons in a nucleus are non-relativistic. Any theoretical treatment of a dynamical system in which relativistic effects are ignored.

NON - RELATIVISTIC QUANTUM MECHANICS. See **quantum mechanics (nonrelativistic).**

NONSELF-MAINTAINING DISCHARGE. See **Townsend discharge.**

NON - SPECULAR REFLECTION IN ACOUSTICS. The reflection from rough surfaces, which produce **diffraction** and **scattering** of sound waves.

NONSTORAGE CAMERA TUBE. A camera tube whose output is proportional to the instantaneous light value being received by a basic **picture element** of the **mosiac** at the time of **scanning.**

NORDSTRÖM THEORY OF GRAVITATION. Theory in which the gravitational potentials form a **four-vector** which can be adjoined to the electromagnetic field strengths to form a theory based on five dimensions. Fails to describe correctly the rotation of the **perihelion of Mercury.**

NORM. See **normalization.**

NORMAL. (1) A perpendicular to a line. In a plane, its slope equals the negative reciprocal of the slope of the given line, in space, the given line has direction cosines L, M, N and its normal has the direction cosines λ, μ, ν so that $\lambda L + \mu M + \nu N = 0$. (2) The normal

to a curve or to a surface is the line perpendicular to the **tangent** line or plane at any specified point. (3) A **partial differential equation** is in normal form when written in terms of parameters for its **characteristic curves.** (4) See also **matrix, normal.** (5) A normal derivative (see **derivative, directional**).

NORMAL GLOW. See **glow potential.**

NORMAL INDUCTION. The limiting **induction** in a material which is in a symmetrically, cyclically-magnetized condition.

NORMAL MAGNIFICATION. In telescopes and microscopes the eye is usually placed at the **exit pupil** of the system, and if the full brightness of the object is to be represented in the image, the exit pupil must be of such size as just to fill the pupil of the eye. The particular **magnification** which just meets this condition is called normal.

NORMAL MODE OF VIBRATION. See **vibration, normal mode of.**

NORMAL PRESSURE. The standard pressure to which measurements of volume, especially of gases, and other experimental work which may vary with pressure changes, are usually referred It is the pressure of a column of mercury 760 millimeters high at sea-level at a latitude of 45°.

NORMAL REACTION (I.E., NORMAL TO PATH). The reactive thrust with which a constraining surface acts on a contacting object which in turn is subject to a force with a component perpendicular to the surface. If there is no friction between the surface and the object, the reactive thrust is perpendicular or normal to the surface. An example is an object moving on a frictionless inclined plane. The normal reaction is perpendicular to the plane and has the magnitude $W \cos \theta$ where W = weight of object and θ = angle of plane. The presence of **friction** introduces a component of force parallel to the surface.

NORMAL STATE. In nuclear physics, a term sometimes used for **ground state.**

NORMALIZATION. (1) The process of normalizing a function. If $f(x)$ is real and defined for $a \leqq x \leqq l$ the **norm** of f is

$$N(f) = \int_a^b f^2 dx.$$

Then if a new function

$$\phi(x) = f(x)/\sqrt{N(f)}$$

is defined, it follows that

$$N(\phi) = \int_a^b \phi^2 dx = 1$$

and $f(x)$ is said to be **normalized.** The procedure is readily generalized to include complex functions. (See also **orthonormal.**) (2) In quantum mechanics, it is convenient to normalize the integral of a wave function so that the peak of the function will have some desired value. The conventional time-independent wave equation for the hydrogen atom is normalized so that

$$\int \psi\psi^* d\tau = 1,$$

i.e., the electron should be somewhere in space.

NORMALIZATION FACTOR. The quantity $1/\sqrt{N(f)}$ required to normalize $f(x)$. (See **normalization.**)

NORMALIZED ADMITTANCE. See **admittance, normalized.**

NORMALIZED PLATEAU SLOPE. The slope of the substantially-straight portion of the counting rate versus voltage characteristic divided by the ratio of the counting rate to the voltage at the **Geiger-Mueller threshold.**

NOTCHING FILTER. (1) A **filter** employed in a television transmitter to provide **attenuation** at the low-frequency edge of the channel to prevent possible interference with the sound channel of the lower adjacent channel. (2) Any band-rejection filter which produces a sharp "notch" in the transfer characteristic of a system.

NOTE. A conventional sign used to indicate the pitch, or the duration, or both, of a tone sensation. It is also the sensation itself or the vibration causing the sensation. The word serves when no distinction is desired between the symbol, the sensation, and the physical stimulus.

NOVAL. The basing arrangement for a nine-pin, miniature, glass **vacuum-tube.** The tube pins extend directly through the glass envelope.

***N*th HARMONIC.** The harmonic of frequency N times that of the fundamental component.

NTSC. Abbreviation for National Television System Committee.

NU. (1) Poisson ratio (ν, but μ is preferred). (2) Frequency in optics and atomic physics (ν). (3) Reciprocal of dispersive power (ν). (4) Wave number (ν, but σ is preferred). (5) Reluctivity (reciprocal permeability) (ν), reluctivity of free space (ν_0). (6) Coefficient of kinematic viscosity (ν). (7) Neutrino (ν)

NU-VALUE. See **dispersive power (2).**

NUCLEAR BREEDER. A nuclear **reactor** in which more fissionable material is formed in each generation than is used up in fission.

NUCLEAR CHARGE. The positive charge on the atomic nucleus due to the protons it contains The sum of the charges of the protons in a nucleus, equal to $+Ze$.

NUCLEAR DISINTEGRATION. See **disintegration, nuclear.**

NUCLEAR EMULSION. A type of photographic emulsion, used to register the track of a charged particle as a series of dark grains, visible on microscopic examination. Various nuclear emulsions are available for detection of different particles; they are thicker and more concentrated than ordinary photographic emulsions, and are often supported on a glass sheet, called a nuclear plate

NUCLEAR ENERGY. Energy released in nuclear reactions. (See **disintegration energy, nuclear.**)

NUCLEAR ENERGY LEVELS. Differ... in the energy of atomic nuclei. As in the case of atoms, nuclei can assume only a discrete number of **energy levels.**

NUCLEAR EQUATION. An equation showing the changes in composition, usually in terms of mass number and charge only, of an atomic **nucleus** during a nuclear reaction. The equation shows any particles captured, or radiations absorbed by the nucleus, and also the particles or radiations emitted. See **nuclear reaction** for examples

NUCLEAR FISSION. See **fission, nuclear.**

NUCLEAR FORCES. Nonelectromagnetic forces between and peculiar to nucleons. Sometimes called specifically nuclear forces to emphasize that they do not include electrostatic and magnetic forces, even though the latter are operative in nuclei. Nuclear forces are of short range, are predominantly attractive, and are nearly, if not completely, charge-independent; that is, the neutron-neutron, neutron-proton, and proton-proton specifically nuclear interactions are almost identical in character. The meson theory of nuclear forces, due originally to Yukawa, postulates the existence of a particle, now called a **meson,** the exchange of which between two nucleons is responsible for the force between them. These mesons may be positive, negative or neutral, and are presumed to be identical with π-mesons.

In phenomenological treatments of nuclear forces, it is usually assumed that the forces act between pairs of nucleons (the force between any pair being independent of the presence of other nucleons) and that they are derivable from (can be written as the gradient of) a velocity-independent potential function The nuclear force may be a **central force,** being a simple attraction or repulsion directed along the line joining the pair, or it may be a noncentral, or tensor, force whose direction depends in part on the spin orientation of the nucleons It may also be an ordinary, or **Wigner force,** or an exchange force of the **Majorana, Bartlett,** or **Heisenberg** type.

NUCLEAR FUEL. The fissionable material used in a **nuclear reactor.**

NUCLEAR INDUCTION. Magnetic induction in material samples (which may be solid, liquid or gaseous) that has its origin in the magnetic moments of the constituent nuclei This effect is due to the unequal population of energy states available when the material is placed in a magnetic field. Nuclear induction is usually weak, but may be readily observed in the Bloch type of experiment depending upon the occurrence of **nuclear magnetic resonance.**

NUCLEAR ISOBAR. See **isobar, nuclear.**

NUCLEAR ISOMER. See **isomer, nuclear.**

NUCLEAR ISOMERISM. See **isomerism, nuclear.**

NUCLEAR MAGNETIC ALIGNMENT. Evidence of nuclear alignment has been obtained by studying radioactive emanations from atoms such as Co^{60} and Co^{58} in very low temperature ranges (0.01–0.05°K). Radioactive particles are emitted with a preferred direction in space which is determined by alignment of the **nuclear magnetic moment.** Studies have already led to some information about the excited state of the radioactive nucleus. Evidence for nuclear magnetic polarization has been obtained by preferential scattering of neutron beams.

NUCLEAR MAGNETIC MOMENT. An electrically-charged particle possessing angular momentum will act like a small magnet and thus possess a magnetic moment of order $eh/4\pi mc$, where e is the charge in esu, h is the **Planck constant,** m is the mass of the particle, c is the velocity of light

NUCLEAR MAGNETIC MOMENTS, DETERMINATION BY RABI METHOD. See **Rabi method.**

NUCLEAR MAGNETIC RESONANCE. The resonance phenomenon met with in energy transfer between a radiofrequency alternating magnetic field and a nucleus placed in a constant magnetic field H that is sufficiently strong to decouple the nuclear spin from the influence of the atomic electrons. Resonance is encountered when $\omega = gh$, where ω is the angular frequency of the alternating field, g the nuclear **gyromagnetic ratio,** and h is the Planck constant. Transitions can then be induced between the various possible substates corresponding to different quantized orientations of the nuclear spin relative to the direction of H. The phenomenon has found application in connection with measurements of g both by molecular beams and by the use of macroscopic samples of solids or liquids. In the latter case, ω is commonly held constant, and H is varied back and forth through the resonance value for the sake of convenience in producing a display upon an oscilloscope. (See **nuclear induction.**)

NUCLEAR MAGNETON. The nuclear Bohr magneton. (See **Bohr magneton, definition (2).**)

NUCLEAR NUMBER. The same as **mass number.**

NUCLEAR PARAMAGNETISM. Paramagnetism associated with **nuclear magnetic moments.** The susceptibility of solid hydrogen (which is diamagnetic with respect to electrons but paramagnetic with respect to protons) has been measured at very low temperatures and found to be consistent with the known magnitude of the proton magnetic moment.

NUCLEAR PARTICLE. A particle believed to exist as such in the nucleus of atoms or of certain atoms. (See **nuclear structure.**)

NUCLEAR PLATE. See **nuclear emulsion.**

NUCLEAR POLARIZATION. Alignment of the **spin magnetic moments** of atomic nuclei in the same direction, giving a net macroscopic magnetic moment.

NUCLEAR POTENTIAL. See **potential, nuclear.**

NUCLEAR POTENTIAL ENERGY. See **potential energy, nuclear.**

NUCLEAR POWER. Economically useful power released in exothermic nuclear reactions. (See **reactor, nuclear.**)

NUCLEAR, RADIUS. The radius R of a spherical volume within which the density of nucleons in a nucleus is effectively large. It is not a precisely determinable quantity. Theory indicates that the density of nucleons tapers off gradually at the edge of the nuclear volume and that this volume is somewhat eccentric. Each type of experiment serving to determine the radius of a nucleus yields a slightly different value Thus, it is sometimes necessary to specify the neutron collision radius, determined by fast neutron transmission experiments; the Coulomb, or Gamow, barrier radius, deduced from the rate of **α-disintegration** or from cross sections of nuclear reactions involving charged particles; the electrostatic radius, deduced from an analysis of nuclear **binding energies,** especially of **mirror nuclides.** The radius parameter r_0 is the effective radius of a nucleus divided by the cube root of its **mass number** A. All experiments yield approximately the same value of r_0 for all nuclei, thus indicating that nuclei have about the same density. The most precise value is given by experiments with elec-

tron scattering and μ-mesonic atoms. Thus the formula

$$R = r_0 A^{1/3} = 1.2 \times 10^{-13} A^{1/3} \text{ cm}$$

is quite good for calculating the radius of any nucleus.

NUCLEAR REACTION. An induced nuclear disintegration, that is, a process occurring when a nucleus interacts with a photon, elementary particle, or another nucleus. In many cases the reaction can be represented by a symbolic equation similar to the following:

$$_7N^{14} + {_2He^4} \rightarrow {_8O^{17}} + {_1H^1}$$

or in the form:

$$_7N^{14} + \alpha \rightarrow {_8O^{17}} + p$$

or in the form:

$$_7N^{14}(\alpha,p)_8O^{17}.$$

NUCLEAR REACTION, REACTION ENERGY OF. The energy either absorbed or emitted in a **nuclear reaction.**

NUCLEAR REACTION, RESONANCE CONCEPT OF. Nuclei exist in discretely spaced energy levels, which may be observed through the increase in reaction **cross sections** at the energies corresponding to the levels.

NUCLEAR REACTION, THRESHOLD ENERGY OF. Certain reactions are energetically impossible unless the bombarding particle has a certain minimum energy, known as the threshold energy. For example, the (γ,n) reaction cannot take place unless the bombarding photon has an energy equal to or greater than the **binding energy** of the neutron.

NUCLEAR REACTOR. See **reactor, nuclear** and succeeding terms for all reactor definitions.

NUCLEAR SPIN. See **spin, nuclear.**

NUCLEAR SPIN EFFECT. See discussion under **spectrum, hyperfine.**

NUCLEI, EQUIVALENT. See **equivalent nuclei.**

NUCLEOGENESIS. Formation of nuclei in nature on a large scale.

NUCLEON. A constituent particle of the **nucleus** of the atom.

NUCLEONICS. The applications of nuclear science in physics, chemistry, biology and other sciences, including military science, and in industry, and the techniques associated with these applications.

NUCLEUS. The interior or central part, or the kernel. The term nucleus is widely used in science, as the nucleus of a cell, the nucleus of an atom or the nucleus of a molecule. The nucleus of an atom is the positively-charged core, with which is associated practically the entire mass of the atom, but only a minute part of its volume. The nucleus of a molecule is a group of atoms connected by valence bonds so that the atoms and their bonds form a ring or closed structure, which persists as a unit through a series of chemical changes.

NUCLEUS, COMPOUND. An excited nucleus constituting an intermediate stage in an induced nuclear reaction (see **reaction, nuclear**), and having a long lifetime compared with the normal transit times of nuclear particles across the nucleus (about 10^{-22} sec), as a result of the sharing of the excitation energy among the constituent **nucleons.**

NUCLEUS, INDEPENDENT PARTICLE MODEL OF. A model of the nucleus based on the postulate that each nucleon moves independently in a field corresponding to the average positions of all the other nucleons. When applied with the **Pauli exclusion principle** and the postulated existence of strong spin-orbit coupling, this model has explained quite successfully many empirical features of nuclei, such as **nuclear moments, magic numbers, shell structure,** etc.

NUCLEUS, LIQUID-DROP MODEL OF. A model of the atomic nucleus in which it is imagined to behave much like a drop of liquid. The nucleons within the drop are considered to be distributed uniformly, and to be in a state of constant motion similar to the thermal motion of the molecules in a liquid. Each nucleon in the interior has about the same binding energy analogous to heat of condensation. Furthermore the nucleons near the surface are less strongly bound, analogous to the effect of surface tension. When a nucleus is highly excited, as

by a collision, the additional energy is distributed rapidly among all the nucleons, the effect being similar to a rise in temperature. Particles can leave the nuclear surface only relatively slowly, because escape depends upon an accidental concentration of energy in one particle. Thus the **spallation reaction** resembles the evaporation of a liquid. Other assumptions are that the nucleus may vibrate as a whole; and that the effect of an electric charge is similar to that on a liquid drop. The liquid-drop model makes possible a fairly good explanation of nuclear **fission.**

NUCLEUS, RECOIL. An atomic nucleus that recoils, because (1) of a collision with a nuclear particle, or (2) of the emission of a particle from it.

NUCLEUS, RESIDUAL. The heavy nucleus which is the end product of transformation. For example, in the reaction

$$_7N^{14} + {_2He^4} \rightarrow {_8O^{17}} + {_1H^1},$$

the $_8O^{17}$ is the residual nucleus.

NUCLIDE. A species of atom distinguished by the constitution of its **nucleus.** The nuclear constitution is specified by the number of protons Z, number of neutrons N, and energy content; or, alternatively, by the atomic number Z, mass number A $[= N + Z]$, and **atomic mass.** To be regarded as a distinct nuclide, the atom must be capable of existing for a measurable time; thus **nuclear isomers** are separate nuclides, whereas promptly-decaying excited nuclear states and unstable intermediates in nuclear reactions are not so considered.

NULL. Zero, or without action; or, in the case of an instrument, without giving a reading.

NULL CONE. See **light-cone.**

NULL ELECTRODE. See **electrode, null.**

NULL-GEODESIC. Curve drawn in **space-time** such that the infinitesimal interval between two neighboring points on the curve vanishes. This represents a possible **space-time path** of a light ray.

NULL LINE. See **Fortrat parabola.**

NULL-LINE GAP. See **Fortrat parabola.**

NULL METHOD OF MEASUREMENT. Any method of measurement in which adjustments of the apparatus are made until a **detecter (2)** shows no indication of a signal. Such methods are often more accurate than are deflection methods in which instrument calibration errors may be serious. **Bridge** and **potentiometer** measurements are examples.

NULL VECTOR. A vector A_μ of zero length $(A_\mu A_\mu = 0)$. In special relativity theory the displacement between two **events** on the path of a photon is a null vector.

NULLITY (DEGREES OF FREEDOM ON MESH BASIS). The number of independent **meshes** that can be selected in a **network.** The nullity N is equal to the number of **branches** B, minus the number of **nodes** V, plus the number of separate parts P. $N = B - V + P$.

NUMBER. (1) The symbols used for counting and in arithmetic, or the abstract mathematical entities they represent. Numbers are further described as being **prime, integral, fractional, irrational.** In algebra and other branches of mathematics, letters are often used for numbers. **Algebraic numbers** satisfy a polynomial equation in one variable with integral coefficients. **Transcendental numbers** are not algebraic. Two familiar ones of this kind are $e = 2.71828\cdots$ and $\pi = 3.14159\cdots$ Other transcendental numbers are known by the names of mathematicians who studied them: **Bernoulli, Stirling** numbers, etc. **Complex numbers** are values of the **complex variable.** (2) A sequence of pulses. (3) In a digital machine, a word composed only of digits and possibly a sign.

NUMBER, PRIME. An **integer** with no integral factors other than itself or unity. The first few prime numbers are 1, 2, 3, 5, 7, 11, 13, 17, 19, 23, $\cdots$.

NUMERICAL APERTURE. (See **Abbe sine condition.**) The quantity $n \sin \theta$, that is, the product of the index of refraction of the object medium (generally air) multiplied by the sine of the **slope angle** of the outermost ray from an axial point on the object.

NUMERICAL DIFFERENTIATION. A method for calculating the numerical value of the derivative of a function at a given point (x_0,y_0). Graphical or mechanical processes

may be used, but more commonly the function is approximated with an **interpolation formula** which is then differentiated by the rules of calculus.

NUMERICAL INTEGRATION. Evaluation of a definite integral from pairs of numerical values of the integrand. Graphical or mechanical methods may be used but more frequently the integrand is approximated by an **interpolation formula** which is then integrated term by term. Special cases are the **trapezoidal rule**, the **Simpson rule**, the **Weddle rule**, the **Gauss formula**, the **Euler-MacLaurin formula**. (See also **quadrature** and **cubature**.)

NUMERICAL SOLUTION OF ALGEBRAIC AND TRANSCENDENTAL EQUATIONS. A process for finding the roots, real or complex, of such equations. Graphical procedures are used if low accuracy is sufficient. More exact methods include **Horner's**, **Newton's**, **regula falsi**, **iteration**, **Graeffe's**. Some of them may be generalized for simultaneous equations in several unknowns.

NUMERICAL SOLUTION OF DIFFERENTIAL EQUATIONS. A procedure for finding pairs of variables which satisfy a given differential equation together with given initial conditions. There are graphical and mechanical means as well as analytical methods. Many variations in the latter methods have been proposed but they may usually be classified as: (1) Methods of successive approximations or iteration (see **Euler method**) by means of polynomials or integral equations (see **Picard method**). (2) Expansions in a **Taylor series**. (3) **Runge-Kutta method**. (4) **Milne method**.

NUSSELT NUMBER. The non-dimensional parameter, defined as

$$N_\mu = \frac{Q}{\Delta T}\frac{d}{k}$$

where Q is the heat loss from a solid body, ΔT is the difference of temperature between the body and its surroundings, d is the scale size of the body, k is the thermal conductivity of the surrounding fluid. The Nusselt number is useful in the reduction of measurements of free and forced convective loss of heat either from the same body in different conditions or from different bodies of geometrically-similar shapes.

NUTATION. In the case of a spinning top or **gyroscope**, the inclination of the top's axis to the vertical will vary periodically between certain limiting angles. This motion is called nutation. In general a spinning top or gyroscope experiences both nutation and **precession**.

NYQUIST INTERVAL. See **Nyquist rate.**

NYQUIST RATE, SIGNALING. In transmission, if the essential frequency range is limited to B cycles per second, $2B$ is the maximum number of code elements per second that can be unambiguously resolved, assuming the peak interference is less than half a quantum step. This rate is generally referred to as signaling at the Nyquist rate, and $1/2B$ is called the Nyquist interval.

O

O-ELECTRON. An electron having an orbit of such dimensions that the electron constitutes part of the fifth **shell** of electrons surrounding the atomic **nucleus**, counting out from the nucleus (i.e., the K-shell is the first, the L-, the second, the M-, the third, the N-, the fourth, and the O-shell, the fifth).

O NETWORK. A **network** consisting of four **branches** connected in series to form a **mesh**, the four **junction points** forming pairs of input or output terminals.

O-P PROCESS. See **Oppenheimer-Phillips process.**

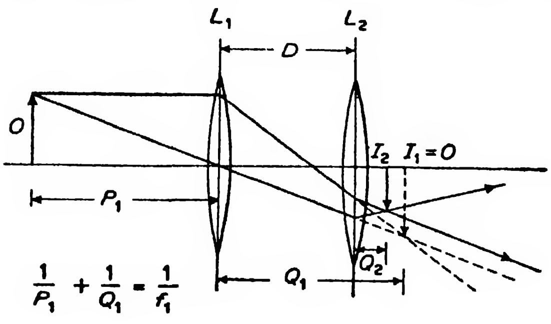
O-SHELL. The collections of electrons characterized by the **quantum number** 5. The O-shell starts with the element rubidium (atomic number = 37), which has one electron in its O-shell, and the O-shell is finally completed (containing 18 electrons) with the element mercury (atomic number = 80). During the progression from rubidium to mercury, the difference between elements of consecutive atomic numbers is frequently not in the O-shell, but in an electron increment in the N-shell, or in the P-shell.

O WAVE. See **ordinary-wave component.**

OBJECT POINT. The real or virtual point of intersection of a pencil of rays incident upon an optical system.

OBJECT, REAL. In geometrical optics, an object is called "real" if from each point of it, light diverges towards the optical system. (See **object, virtual.**) The first object (O) in that diagram is "real."

OBJECT, VIRTUAL. An example of a virtual object is given below. The image I_1 which would have been formed by lens L_1 had not lens L_2 been interposed acts as a virtual object for lens L_2.



$$\frac{1}{P_1} + \frac{1}{Q_1} = \frac{1}{f_1}$$

$$Q_1 - D = P_2$$

$$\frac{1}{-P_2} + \frac{1}{Q_2} = \frac{1}{f_2}$$

OBJECTIVE LENS. Commonly that lens of a system which is toward the object.

OBJECTIVE, OIL-IMMERSION. In order to reduce reflection losses, and also to increase the **index of refraction** of the object space, some high-power microscope objective lenses are designed to have the space between the **objective lens** and the object filled with an oil which has an index of refraction the same as that of the cover glass over the object, and of the objective lens.

OBJECTIVE PRISM. A large prism placed before the **objective lens** of a telescope in order to produce spectral images of stars on a photographic plate in its **focal plane.**

OBLATE. Flattened or depressed at the poles.

OBLATE SPHEROIDAL COORDINATES. The coordinate surfaces are families of oblate **ellipsoids** of revolution around the Z-axis with semi-axes $a = c\sqrt{1 + \xi^2}$, $b = c\xi$ (ξ = const.); **hyperboloids** of revolution of one sheet with $a = c\sqrt{1 - \eta^2}$, $b = c\eta$ (η = const.) and planes from the Z-axis (ϕ = const.). The following additional relations hold:

$$0 \leqq \xi \leqq \infty; \quad -1 \leqq \eta \leqq 1; \quad 0 \leqq \phi \leqq 2\pi$$

$$x = c\sqrt{(1 + \xi^2)(1 - \eta^2)}\cos\phi$$

$$y = c\sqrt{(1 + \xi^2)(1 - \eta^2)}\sin\phi$$

$$z = c\xi\eta.$$

Alternative variables often used are

$$\xi = \sinh u; \quad \eta = \cos v;$$

$$0 \leqq u \leqq \infty; \quad 0 \leqq v \leqq \pi.$$

OBLIQUE-INCIDENCE TRANSMISSION. The name sometimes applied to radio waves received via reflections from the **ionosphere.**

OBLIQUITY FACTOR. While in the wave theory of Huygens (see **Huygens principle**), each point on a wave front is a center from which new spherical waves emerge, the amplitude of these secondary waves is not the same in all directions, being reduced by an

obliquity factor proportional to $1 + \cos\theta$ where θ is the angle between the original wave front and the wave front of a secondary wavelet.

OCCLUDED FRONT. See **occlusion.**

OCCLUSION. (1) A condition of uniform molecular adhesion between a precipitate and a soluble substance, or between a gas and a metal, of such a nature that it is very difficult to separate the occluded substance by washing or other simple mechanical process. Occlusion in precipitates depends upon the distribution of a substance between solvent and solid and is probably due to **adsorption.** Another type of occlusion is that of hydrogen by palladium, which was studied by Graham. (2) In meteorology, when one front overtakes another, forcing one of the fronts upward from the surface of the earth, that front is said to be an occluded front, and the zone in which this condition exists is called the occlusion.

OCTAL BASE. An eight-pin tube-base (some pins may be omitted if unused) with a center aligning **key.**

OCTALUX BASE. Another name for the **loctal base.**

OCTAVE. The interval between two sounds having a basic **frequency ratio** of two. By extension, the octave is the interval between any two frequencies having the ratio 2:1. The interval, in octaves, between any two frequencies is the logarithm to the base two (3.322 times the logarithm to the base 10) of the frequency ratio.

OCTAVE ANALYZER. A **filter** in which the upper cut-off frequency is twice the lower cut-off frequency.

OCTAVE-BAND PRESSURE LEVEL (OCTAVE PRESSURE LEVEL). Of a sound, the band pressure level for a frequency band corresponding to a specified octave The location of an octave-band pressure level on a frequency scale is usually specified as the geometric mean of the upper and lower frequencies of the octave.

OCTAVES, LAW OF. Newland's name for his hypothesis of the periodic system. His arrangement was a simple grouping of the elements in order of increasing atomic weight, beginning with lithium, in horizontal rows of eight elements each, beginning each new row directly beneath the previous one.

OCTET, ELECTRON. A group of eight valence **electrons** which constitutes the most stable configuration of the outermost, or valency, electron-shell of the atom, and hence the form which frequently results from electron transfer or sharing between two atoms in the course of a chemical reaction.

OCTODE. An eight-electrode **electron tube** containing an anode, a cathode, a **control electrode,** and five additional electrodes that are ordinarily **grids.**

OCULAR. A **lens** through which anything is viewed, commonly the lens or lens system in an optical instrument in the end through which the image is viewed by the eye.

OCULAR, NEGATIVE. See **Huygens eyepiece.**

ODD-EVEN NUCLEI. Nuclei which contain an odd number of protons and an even number of neutrons

ODD-EVEN RULE OF NUCLEAR STABILITY. The rule, based on the number of stable **nuclides,** that nuclides with even numbers of both protons and neutrons are most stable; those with an even number of protons and an odd number of neutrons, or vice-versa, are somewhat less stable; while those with odd numbers of both protons and neutrons are least stable.

ODD MOLECULES. A few, unusual molecules that have an odd number of valence electrons.

ODD-ODD NUCLEI. Nuclei which contain an odd number of protons and an odd number of neutrons.

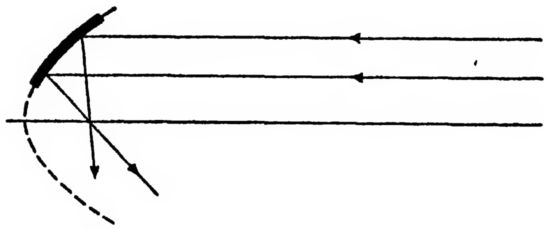
ODD TERM OF ATOM. A term for which Σl_i, summed over all the electrons of the atom, is odd. The eigenfunctions of odd terms are changed in sign by reflection of all particles at the origin.

In work on atomic spectra the odd terms are distinguished from the even ones by a superscript o (e.g., $^2P^o$) while in work on molecular spectra, the subscripts g and u are used for even and odd terms, respectively (e.g., ^2P_g, ^2P_u).

OERSTED. A unit of **magnetic field strength** in the **emu system.** The magnetic field produced at the center of a plane circular coil of one turn, and of radius one centimeter, which carries a current of ($1/2\pi$) abamperes.

OERSTED EXPERIMENT. See **electromagnetism.**

OFF-AXIS PARABOLIC MIRROR. A mirror in the shape of a **paraboloid** of revolution will reflect a parallel beam to a single focus within the incident beam, if the beam is parallel to the axis of the paraboloid. In order to reflect a beam to a point off of the original



beam, a part only of a paraboloidal mirror is used. Such a part is therefore known as an off-axis parabolic mirror. It is commonly manufactured by cutting it from the larger total paraboloid, because of the difficulty of making small, paraboloidal sections.

OFFENSE AGAINST THE SINE CONDITION. Abbreviated to OSC. A quantity introduced into lens design by A. E Conrady in order to have a numerical measure of **coma,** and defined as the ratio of the sagittal coma to the distance of the image point from the optical axis. (See Conrady, *Applied Optics and Optical Design.*)

OHM. A unit of electrical resistance, symbol, Ω. (1) The absolute ohm is defined as the resistance of a conductor which carries a steady current of one absolute ampere when a steady potential difference of one absolute volt is impressed across its terminals. This is equivalent to the statement that the conductor dissipates heat at the rate of one watt when it carries a steady current of one absolute ampere. The absolute ohm has been the legal standard of resistance since 1950. (2) The International ohm, the legal standard before 1950, is the resistance offered to a steady electric current by a column of mercury of 14.4521 gm mass, constant cross-sectional area, and a length of 106.300 cm, at 0°C.

$$1 \text{ Int. ohm} = 1.000495 \text{ abs. ohm.}$$

OHM, ACOUSTICAL. See **acoustical ohm.**

OHM LAW. This very familiar law of **electric conduction,** stated by George Simon Ohm in 1827, is expressible in various forms, of which the following is typical: The steady electric current in a metallic circuit is proportional to the constant total electromotive force operating in the circuit: $I = KE$. The constant K, known as the "conductance" of the circuit, is the reciprocal of the **resistance** R; so that the equation may be written in the more usual form

$$I = \frac{E}{R}.$$

Emphasis must be placed on the constancy of the electromotive force and the current. For, if the current varies, the effects of **inductance** and **capacitance** set up extra electromotive forces, positive or negative, which render the law expressible in general only by a differential equation. (See **transients, alternating currents,** and **electric circuits.**) Also there are certain kinds of conduction for which the law is not valid; notably that of **ionized gases, thermionic vacuum tubes** and **photoelectric cells.**

OHM, MECHANICAL. By analogy with the concept of electrical impedance, the complex ratio of the force acting in a mechanical system to the velocity is often termed the mechanical impedance and is measured in mechanical ohms. In the cgs system, the mechanical ohm is equal to 1 dyne per cm/sec, and has the dimensions of gm/sec. (See also **acoustic units.**)

OHMIC CONTACT. A contact between two materials, possessing the property that the potential difference across it is proportional to the current passing through.

OHMMETERS. The accurate measurement of resistance is somewhat tedious, and various instruments have been devised to make direct readings in ohms. For example, one may send a current from a source of known electromotive force E and known internal resistance R_i through an unknown resistance R_x, a voltmeter being placed across the **terminals**

to register the resulting potential drop V. From these the resistance can be calculated; for

$$V = \frac{R_x}{R_i + R_x} E,$$

from which

$$R_x = \frac{VR_i}{E - V}.$$

Obviously, for a given, fixed electromotive force, the voltmeter scale might be graduated directly in ohms. But the reliability of such an instrument requires a strictly constant electromotive force. The more approved types of ohmmeter use the slide-wire **bridge** principle, with the slide-wire scale graduated in ohms. These instruments, though accurate, are necessarily somewhat restricted in range. A form of high-resistance ohmmeter, designed by Evershed, is graduated in megohms and is known commercially as a "megger." This is a type of differential, moving-coil galvanometer, in which part of the coil is in series with the unknown resistance, while another part, carrying current from the same source, is independent of that resistance. The galvanometer reading depends upon the relative currents in the two parts, and hence upon the unknown resistance.

Many modern ohmmeters consist of a vacuum tube voltmeter of adjustable resistance (R_v) which is connected in series with a source of emf (E) and the unknown resistance (R_x). Then

$$R_x = \frac{R_v(E - V)}{V}$$

where V is the voltmeter reading.

OMEGA. (1) Solid angle (ω). (2) Angular frequency (ω). (3) Angular frequency with damping (ω). (4) Dispersive power (ω). (5) Periodicity or pulsetance (ω). (6) Resonance periodicity (ω_r). (7) Specific magnetic rotation, or Verdet constant (ω). (8) Volume of phase space (Ω). (9) Absolute value of the projection of the total angular momentum of a single electron on the molecular axis (Rydberg-type, Case c) (ω). (10) Designation of Hund's Case c state of electronic state of a molecule (Ω, Ω_g or Ω_u).

OMEGATRON. A small form of **cyclotron** used chiefly for purposes of instrumentation.

OMNIDIRECTIONAL ANTENNA. See **antenna, omnidirectional.**

OMNIGRAPH. A device for the audible reproduction of Morse code signals from a perforated tape for instructional purposes.

ONDOSCOPE. An electric wave detector consisting of a **glow-discharge tube.**

ONE-GROUP MODEL. A model for the study of neutron behavior in which neutrons of all energies are treated as having the same characteristics.

ONSAGER EQUATION. An equation expressing the relation between the measured equivalent **conductance** at a particular concentration to that at infinite dilution.

ONSAGER THEORY OF DIELECTRICS. It is proposed that the treatment using the **Lorentz field** is wrong for dielectrics containing permanent dipole moments. Instead of taking the local field as

$$E_{loc} = E_0 + \frac{4\pi}{3} P$$

where E_0 is the external field and P is the polarization, the relation

$$E_{loc} = \frac{3\epsilon}{2\epsilon + 1} E_0$$

is derived from a simple model of a spherical cavity in a medium of dielectric constant ϵ Combining this with the **Langevin function** for the polarization induced by the local field gives a formula for the dielectric constant which does not show a **polarization catastrophe.**

OPACITY. Imperviousness to radiation, especially to light; the property of stopping the passage of light rays numerically expressed as the reciprocal of the **transmittance.** Density (photographic) is the logarithm of opacity to the base 10.

$$d = \log_{10} O = \log_{10} \frac{1}{\tau}$$

where d is density, O is opacity and τ is transmittance.

OPEN SYSTEM. A system allowing interchange of heat and matter with its surroundings, familiar in biology and in continuous reaction processes in the chemical industry.

(See also **closed system,** and **non-equilibrium thermodynamics.**)

OPERAND. A word symbol, or quantity on which an operation is to be performed.

OPERATING CHARACTERISTIC. See **load characteristic.**

OPERATION. In computer terminology: (1) The activity resulting from an **instruction.** (2) The execution of a set of **commands.**

OPERATION CODE. In computer terminology, that part of an **instruction** which designates the operation to be performed.

OPERATION, DUPLEX. The operation of associated transmitting and receiving apparatus in which the processes of **transmission** and **reception** are concurrent.

OPERATIONAL METHODS. Study of the properties of **operators** in the absence of the functions on which they operate or a study of mathematical transformations using symbolic operators. Thus, in the examples given under **operator, commutative** one may write $AB = BA$ and $PQ = I + QP$ where I is the unit operator. By these methods it may be shown that certain operators obey some of the rules of arithmetic or algebra.

OPERATOR. The symbolic direction to perform an operation such as addition, multiplication, differentiation, extraction of roots, etc., or some combination of these operations. Thus the symbol $\partial/\partial x$ is an operator which may act on a function $z(x,y)$ to give the partial derivative of y with respect to x. Similarly, $\nabla \cdot$ is a vector operator which may act on a vector to give the divergence.

OPERATOR, ADJOINT. If a **differential operator** is defined as

$$L(y) = \sum_{i=0}^{n} [f_i(x)y^{(r_i)}]^{(s_i)}$$

then the adjoint operator is

$$\bar{L}(y) = \sum_{i=0}^{n} (-1)^{r_i+s_i}[f_i(x)y^{(s_i)}]^{(r_i)}$$

If $L(y) = \bar{L}(y)$, the operators are self-adjoint. (See also **adjoint equation.**)

OPERATOR, COMMUTATIVE. If the order of applying operators to a function is immaterial, the operators are commutative. Suppose $\mathbf{A} = a+$ and $\mathbf{B} = b+$, with a, b constant, are applied to a function of x, then $\mathbf{AB}f(x) = a + b + f(x) = \mathbf{BA}f(x)$ and $\mathbf{A}$, $\mathbf{B}$ commute. However, if $\mathbf{P} = \partial/\partial x$ and $\mathbf{Q} = x$, then $\mathbf{P}$ and $\mathbf{Q}$ are not commutative for $\mathbf{PQ}f(x) = f(x) + \mathbf{QP}f(x)$. (See also **commutator.**)

OPERATOR, CREATION. See **creation operator.**

OPERATOR, DESTRUCTION. See **destruction operator.**

OPERATOR, DIFFERENTIAL. A symbolic operator involving one or more differentiations. Examples are

$$D = d/dx, \quad D^2 = d^2/dx^2, \quad D^{(n)} = d^n/dx^n;$$
$$L = d^2/dx^2 + p(x)d/dx + q(x).$$

(See also **operator, vector; del; d'Alembertian; Laplacian.**)

OPERATOR, DYADIC. A symbolic operator containing functions of a **dyadic.**

OPERATOR, INVERSE. An operator symbol which cancels the process directed by another operator. Thus A, B are inverse operators if they mean addition and subtraction of a constant, respectively, or if they are defined as differentiation and integration.

OPERATOR, LINEAR. A symbolic operator which obeys the distributive law, $\mathbf{A}[f(x) + g(x)] = \mathbf{A}f(x) + \mathbf{A}g(x)$, and for which $\mathbf{A}[cf(x)] = c\mathbf{A}f(x)$, where c is any constant.

OPERATOR, MATRIX. An operator represented by a **matrix.** It transforms a matrix (usually a vector in n-dimensional space) into another matrix (or vector). For matrix operators with special names see the appropriate entries under matrix, as **matrix, Hermitian; matrix, orthogonal;** etc.

OPERATOR, TENSOR. A symbolic operator containing the components of a **tensor.**

OPERATOR, UNIT. A symbolic operator which leaves every other operator unchanged. Thus if indicated by $\mathbf{I}$, $\mathbf{IA} = \mathbf{AI} = \mathbf{A}$ for any definition of the operator $\mathbf{A}$. Also called the identity operator.

OPERATOR, VECTOR. A symbolic operator containing vector quantities. Those fre-

quently used include **del,** the **Laplacian operator,** the **d'Alembertian operator.**

OPERATORS, WAVE MECHANICAL. In setting up the wave mechanics and the quantum mechanics (see **Schrödinger representation** and **Heisenberg representation**) one adopts the formalism that there corresponds to every physical magnitude an **operator** A which acts upon a wave function ψ and transforms it to another function, ϕ. Then, if

$$\phi = A\psi = a\psi$$

where a is a constant, ψ is an eigenfunction of A and a is an eigenvalue of A. The operators of most importance are:

For momentum component p_x,

$$A = -i\hbar\frac{\partial}{\partial x}.$$

For energy E,

$$A = i\hbar\frac{\partial}{\partial t}.$$

The wave mechanical operators in general are not **commutative.**

OPHTHALMOSCOPE. An instrument made up of lenses, and producing a beam of light by means of which the retina of the eye can be seen. It is one of the valuable diagnostic instruments as in many diseases significant findings are present in the eye grounds

OPPENHEIMER-PHILLIPS PROCESS. A mechanism of the (d,p) reaction. In this mechanism the proton of the incident deuteron is thought to be repelled by the **Coulomb force** between it and the target nucleus, while the neutron of the incident deutron approaches close enough to the target nucleus to have a chance of becoming bound sufficiently to overcome its rather small binding energy in the deuteron. The result is a disruption of the deuteron, with the capture of the neutron and repulsion of the proton. Complete penetration of the Coulomb barrier by the proton is not required, and therefore the effect evidences itself in the range of bombarding energies below the Coulomb barrier height, that is, commonly below 10 mev. The effect is a special case of **stripping.**

OPPOSITION. A phase difference of one-half cycle.

OPTAR. A method of optical automatic **ranging** as applied to a guidance device for the blind.

OPTIC AXIS. See **axis, optic.**

OPTICAL ACTIVITY. The power of a substance to rotate the plane of **polarized light** transmitted through it.

OPTICAL ANOMALY. The behavior of certain organic compounds, such as those whose molecules contain conjugated **double bonds,** in which the observed values of the **molar refraction** are not in accord with the values calculated from the known equivalents. When the observed values are higher than the calculated values, the substance is said to exhibit **optical exaltation.**

OPTICAL ANTIPODES. Two compounds composed of the same atoms and atomic **linkages,** which differ in their structural formulas only in that one is the mirror image of the other. The term is commonly applied to substances containing an asymmetric atom, or bond, in which the plane of polarized light is rotated to the right by one of the **optical antipodes,** and to the left by the other.

OPTICAL AXIS. See **axis, optical.**

OPTICAL CENTER (OF A LENS). A point so located on the axis of a lens that any ray, which in its passage through the lens passes through this point, has its incident and emergent parts parallel.

OPTICAL DENSITY (PHOTOGRAPHIC). The logarithm to base 10 of the inverse of the **transmittance** of the developed photographic image.

OPTICAL EXALTATION. The phenomenon whereby a compound possesses a **refraction** different from the value calculated from the various equivalents of the atoms and other structural units of which it is composed. This property is more strictly called **optical anomaly,** but since in most cases the difference is positive, i e , the observed value exceeds the calculated one, the term exaltation is used.

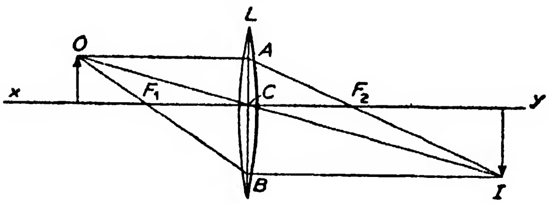
OPTICAL GLASS. Glass to be useful for lenses, prisms and other optical parts through which light passes, as distinguished from mir-

rors, must be completely homogeneous. This includes freedom from bubbles, striae, seeds, strains, etc. In order to reduce **aberrations,** the optical designer needs many different kinds of glass. A few typical sorts are given in the table.

	Type	n_D	ν-Number
Borosilicate	Crown	1.5170	64.5
Barium	Crown	1.5411	59.5
Spectacle	Crown	1.5230	58.4
Light	Flint	1.5880	53.4
Ordinary	Flint	1.6170	38.5
Dense	Flint	1.6660	32.4
Extra dense	Flint	1.7200	29.3

The ν-number is the reciprocal of the **dispersive power** of the glass.

OPTICAL IMAGES, GRAPHICAL CONSTRUCTION. The image of a **point object** may be located to first order accuracy by drawing any two of three easily located lines.



Given a lens L, its **optical axis** x-y, its foci F_1, and F_2 and an object point O.

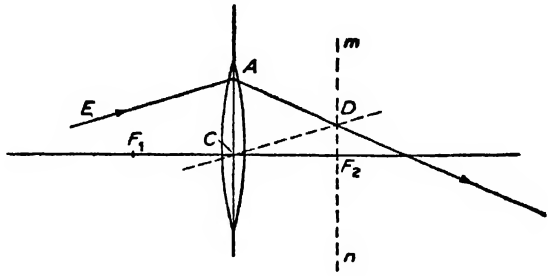
(1) Draw a line OA parallel to x-y and then the line AF_2.

(2) Draw a line OF_1, extend it to the lens at B, and then extend it from B parallel to the optical axis.

(3) Draw the line OC, and continue it without deviation through the lens.

The three lines should meet at the point I, the image of O. If instead of converging to a point the three lines are diverging, trace each of them back and they should meet at a point to the left of the lens indicating a **virtual image.** If the three lines are parallel the image is at infinity. This same method of construction may be applied to any lens or curved mirror.

These are the three easily located lines. If it becomes desirable to trace some other ray (tracing a single ray through more than one lens) the following construction holds.



EA is the ray to be traced through the lens. Draw mn through F_2 perpendicular to the optical axis. Draw CD parallel to EA. The ray will follow the path AD after leaving the lens.

OPTICAL INSTRUMENTS. Optical instruments may be divided into two general classes: (1) those used for optical projection, such as the stereopticon and the **camera;** and (2) those used as an aid to natural **vision,** such as the **telescope** and the **microscope.** In the first class, a real image of the object to be represented is formed on a screen or photographic plate by means of a lens system or a mirror. In the second, the eye of the observer is placed so as to view a virtual image formed by the optical system as a whole, which may or may not involve the formation of a real image in the interior of the instrument (See **geometrical optics, magnifying power,** and **vision.**)

OPTICAL ISOMERISM. The difference in **optical activity** among the isomers of compounds having asymmetric atoms or bonds.

OPTICAL ISOMERS. Two or more compounds which have the same chemical composition and the same two-dimensional structural formulas, but which differ in the spatial arrangement of the atoms or groups about one or more asymmetric atoms or bonds that are present, so that the plane of **polarized light** is rotated in a different direction (left or right) or to a different amount (if the substance has more than two optical isomers).

OPTICAL LENGTH. Equivalent to **optical path.**

OPTICAL LEVER. A common device for amplifying and measuring small rotations. The object rotated carries a small mirror, which, reflecting a beam of light, deflects it through twice the angle of rotation to be measured.

OPTICAL MODE. A type of **thermal vibration** of a **crystal lattice** whose frequency is nearly independent of wave number. The optical modes may be thought of as internal vibrations of the molecules or **unit cells** of the lattice, loosely coupled from cell to cell. In ionic crystals, this leads to strong absorption in the infrared because of the fluctuating dipole moment as the ions of opposite sign move relative to one another. The optical modes contribute to the specific heat with **Einstein specific heat functions.**

OPTICAL PATH. In a medium of refractive index n, the product of the geometrical distance d and the refractive index. When there are several segments $d_1, d_2, \cdots$ of the light path in substances having different indices $n_1, n_2, \cdots$, the optical path is found from the relationship:

$$\text{Optical Path} = n_1 d_1 + n_2 d_2 + \cdots = \sum_i n_i d_i,$$

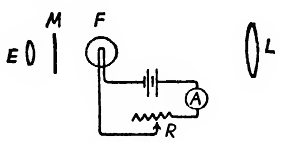
and in a medium in which n varies continuously:

$$\text{Optical Path} = \int n ds,$$

where ds is an element of length along the path According to the **Fermat principle**, the optical path connecting two points has an extreme value.

OPTICAL PATTERN (CHRISTMAS TREE PATTERN). In mechanical recording, a pattern which is observed when the surface of a record is illuminated by a light beam of essentially parallel rays.

OPTICAL PYROMETER. Several **pyrometers** have been devised, by means of which the temperature of a very hot surface is determined from its incandescent **brightness.** One commercial type is illustrated in the figure.



Arrangement of parts of optical pyrometer (diagrammatic)

The hot body is viewed through a sort of telescope, whose objective L produces at F a real image of the glowing surface. At this point a lamp filament F is placed, which is thus viewed through the eyepiece E against the hot surface as a background. A monochromatic filter M is interposed before both, so that their brightness is compared in one spectral region only. The current in the filament is so adjusted by means of the rheostat R that the filament becomes invisible against the bright background. The ammeter A then gives the current, from which the temperature may be deduced; or the ammeter scale may be graduated to read temperatures directly. In another type the balance is secured by keeping the current constant and introducing an absorbing wedge between the filament and the objective, as in a **wedge photometer.** In still others, the temperature is determined, not by the total brightness, but by the relative brightness at two selected wavelengths.

OPTICAL ROTATION. See **polarized light.**

OPTICAL ROTATORY POWER. The ability of a substance to rotate the plane of **polarized light.**

OPTICAL SOUND RECORDER. See **sound recorder, photographic.**

OPTICAL SOUND REPRODUCER. See **photographic sound reproducer.**

OPTICAL SUPERPOSITION, PRINCIPLE OF. Van't Hoff's assumption that the optical **rotation** of a compound composed of two oppositely optically active radicals is the algebraic sum of the separate rotations of each radical. It does not hold in all cases.

OPTICAL TRANSMITTANCE. See **transmittance.**

OPTICALLY-PLANE (OPTICALLY-FLAT). Departing from a true plane only by distances small compared with the wavelength(s) of light concerned.

OPTICALLY VOID LIQUIDS. Liquids that do not exhibit the **Tyndall effect,** e.g., liquids that contain no suspended solids.

OPTICS. Originally that branch of physical science which treats of the phenomena of light and of vision. Today, because of the constantly increasing importance of ultraviolet and infrared radiation, optics has come to include all phenomena associated in any way with electromagnetic waves with wavelengths greater than x-rays and shorter than micro-

waves. Numerical limits of this wavelength region are not definitely defined.

Since the advent of devices such as the **electron microscope** and the **cathode ray tube,** in which beams of particles are focused to form images, the study of the behavior of such instruments is also called optics, usually with an appropriate modifier.

OPTIMUM MAGNIFICATION. The maximum value of the **numerical aperture** of a dry lens is 1.0. Oil-immersion **objectives** with numerical apertures up to 1.65 have been constructed. The minimum distance between points which are just resolved is thus 2.7×10^{-5} cm for a dry lens, and 1.6×10^{-5} cm for an oil-immersion lens, using oblique illumination and a wavelength of 5500 Å. The maximum useful magnification is thus about 800 for dry objectives, and 1200 for **oil-immersion objectives.**

OPTIMUM WORKING FREQUENCY. See **frequency, optimum working.**

OPTOMETRY. A branch of **optics** dealing with the optical performance of the individual eye, and with measurements upon it.

OPTOPHONE. A photoelectric device which converts ordinary printing into audible sounds that can, after suitable training, be identified with individual letters. A reading device for the blind.

ORBIT SHIFT COILS (BETATRON, SYNCHROTRON). A set of coils, usually placed on the magnet pole faces in the region of the stable orbit, through which a pulse of current is passed to alter momentarily the guiding field in such a way as to cause the orbit radius to increase or decrease, or the plane of the orbit to rise, lower or tilt, thereby causing the accelerated particles to strike a target placed outside the stable orbit or to enter a deflector for the production of an external beam.

ORBITAL. In the old quantum theory an electron in a field of force was thought of as moving in an orbit. In **wave mechanics** this idea is expressed by a **wave function** giving the probability of finding the electron in the region. There is, in general, a wave function corresponding to each quantized orbit, and such a wave function has been called an orbital. Although it is never strictly correct to discuss an electronic system as if each electron had a definite wave function, independent of the other electrons, this is often a good approximation. The problem of calculating **valence** forces, according to the modern theory, is then reduced to that of finding the different possible electronic wave functions in the fields of the atomic **nuclei,** allowing for the **exchange** interactions between them. As a starting point for such a calculation, one may choose a series of **atomic orbitals,** where the wave functions are as if concentrated about independent atoms, and try to choose suitable linear combinations of these to represent the true wave functions. Alternatively, one may start with a series of **molecular orbitals,** for example wave functions suitable to describe electrons moving about two centers of force as in a hydrogen molecule, and associate these, or linear combinations of them, with the different **valence bonds** in the structure.

ORBITAL, ANTIBONDING. An **orbital** whose energy increases monotonically as the two atoms to which it belongs move closer—hence an orbital which does not lead to closer binding of the molecule.

ORBITAL, BOND. An **orbital** which may be associated with a definite chemical **bond.** Thus, it is sometimes possible to construct an electron eigenfunction which is concentrated in the region between two atoms in a molecule, and whose energy shows a minimum when the atoms are placed at some small distance apart Then, if electrons are available to fill the orbital, there will evidently be a tendency for a bond to form between the atoms. Bond orbitals may often be **hybridized** combinations of **atomic orbitals** of various types, and may show directional properties.

ORBITAL, BONDING. See **orbital, bond.**

ORBITAL ELECTRON CAPTURE. See **electron capture.**

ORDER. Used with several different meanings. (See **difference, finite; derivative, higher; differential equation; determinant; matrix; diffraction grating;** and next four entries.)

ORDER-DISORDER TRANSFORMATION. Certain **substitutional alloys** are capable of forming compounds of definite composition (e.g., CuAu), where after careful annealing,

a regular **superlattice** structure is found. Thus, in Cu_3Au, for example, the gold atoms appear at the corners of the unit cube, the copper at the face centers. The transformation from a disordered state to the ordered state occurs rather slowly, at a more or less definite temperature. If the alloy is quenched too rapidly through this temperature, only the random structure is observed. (See also **long range order; short range order.**)

ORDER OF. (1) If a function $f(x)$ becomes $|x^k f(x)| < K$ as x approaches 0 or ∞, where K is a positive number independent of x and not zero, then $f(x)$ is said to be of **order** x^{-k}. In symbols, $f(x) = O(x^{-k})$, where this notation is called the ordosymbol. The limited process 0 or ∞ is not always stated explicitly but inferred from the context. In the special case where $\lim |x^k f(x)| = 0$, one writes $f(x) = o(x^{-k})$. (2) When two quantities having the same physical dimensions differ by a small factor, say less than ten, they are said to be of the same order (of magnitude) and one is said to be of the order of the other.

ORDER OF INTERFERENCE. Two light rays with a path difference of an integral number, p, of wavelengths will interfere constructively. p is called the order of the interference.

ORDER OF PHASE TRANSITION. In such phase transitions as **fusion** or **vaporization,** the two phases generally have distinctly different properties (e.g., densities). Such transitions are known as first order transitions. At a given pressure they take place sharply at a fixed temperature and with the absorption or release of latent heat (see **heat, latent**). In some other transitions as that of a liquid to a vapor at the critical point, properties such as density do not show a discontinuous change, although their derivatives with respect to temperature do. Changes of this type are known as second order if the first derivatives change sharply; as third order if the second derivatives undergo such change; etc Second order transitions do not involve latent heats, but the specific heat vs. temperature curve shows anomalies near the transition temperature.

ORDINARY POINT. A value of the complex variable, z, for which a function of this variable, $f(z)$, is analytic. Any point which is not an ordinary point is a **singular point.**

ORDINARY RAY. See **double refraction.**

ORDINARY-WAVE COMPONENT. That **magneto-ionic wave** component deviating the least, in most of its **propagation** characteristics relative to those expected for **a wave** in the absence of the earth's magnetic field. More exactly, if at fixed electron density, the direction of the earth's magnetic field were rotated until its direction is transverse to the direction of **phase propagation,** the wave component whose propagation is then independent of the magnitude of the earth's magnetic field.

ORDINATE. The second coordinate, in addition to the **abscissa,** required to locate the position of a point in a plane. It is measured from the axis of abscissa, usually the X-axis, and along a line parallel to the Y-axis, the axis of ordinates.

ORGAN. A portion or subassembly of a **computer** which constitutes the means of accomplishing some inclusive operation or function, as an arithmetic organ.

ORGANOSOL. A **colloidal system** in an organic dispersion medium.

ORGAN PIPE. As used in physics, this term includes any tube, with one or both ends open, which may resonate at particular frequencies. See **mechanical vibrating system, closed pipe; open pipe.**

ORIENTATION EFFECT. A basis of calculating the attractive forces between molecules, or a component of such forces, from the interaction energy of molecular **dipoles** due to their relative orientation. Also the relation of the bulk properties of a material (such as the **dielectric constant**) to their atomic or molecular properties when the relationship is caused by the reorientation of permanent dipoles by an applied field, rather than by the **polarization** of the atoms or molecules.

ORIFICE. An opening through which a fluid may discharge. The pressure drop across orifices of standard forms is used to measure flow of fluids along pipes and channels.

ORIFICE PLATE. A diaphragm of standardized shape which is inserted in a pipe along which fluid is flowing. If the orifice plate is sharp-edged, the pressure drop across it is

accurately proportional to the square of the flow through the pipe.

OROGRAPHIC LIFTING. The lifting of air caused by its flow up the slopes of hills or mountains.

OROGRAPHIC RAIN. Rain resulting from **orographic lifting.**

OROGRAPHICAL WEATHER PHENOMENA. Any weather phenomena caused by the flow of air over prominent features of the terrain. Air flowing uphill undergoes certain changes because of this **orographic lifting.**

ORTHICON. A camera tube (see **tube, camera**) in which a low-velocity **electron-beam** scans a photoactive **mosaic** which has electrical **storage** capability.

ORTHICON, IMAGE. See **image orthicon.**

ORTHICONOSCOPE. An **orthicon.**

ORTHOBARIC DENSITIES. The density of a liquid and of the saturated vapor in **equilibrium** with it at any temperature.

ORTHOCHROMATIC. The word implies all wavelengths, but as applied to photographic emulsions it means green-sensitive, but not red-sensitive. (See **panchromatic.**)

ORTHOCHROMATIC REPRODUCTION. Loosely defined as the proper (or correct) reproduction of color in monochrome However, since only one characteristic of color, i.e., **brilliance,** can be reproduced in monochrome, orthochromatic photography is more properly described as the correct reproduction of the brilliance characteristic of color into monochrome. In other words, the distribution of sensitivity with wavelength of the film or plate should be the same as that of the eye, which, of course, is represented by the color-brilliance curve.

ORTHOGONALITY. A general term meaning perpendicularity, thus the three axes of a rectangular Cartesian coordinate system are orthogonal in pairs, hence mutually orthogonal. Conditions for orthogonality are readily expressible in vector notation, for if the scalar product of two vectors in two dimensional space vanishes $\mathbf{A}\cdot\mathbf{B} = 0$, the two vectors are perpendicular to each other or orthogonal. The concept is easily generalized to n-dimensional space by assuming two quantities with components A_i, B_i $(i = 1, 2, \cdots, n)$ and they are then orthogonal if

$$\sum_{i=0}^{n} A_i B_i = 0.$$

If the vector space involved has an infinite number of dimensions and if the components A_i, B_i are continuously distributed so that the index i becomes a continuous variable, the two functions are then orthogonal if

$$\int_a^b \mathbf{A}(x)\mathbf{B}(x)dx = 0.$$

The limits of integration are needed to specify the range of x for which the functions are defined. They may be finite or infinite. Arbitrary functions may be made orthogonal by the **Schmidt process.**

ORTHOHELIUM TERMS. One group or system of terms in the spectrum of helium that is due to atoms in which the spin of the two electrons are parallel to each other. Another group of spectral terms, the parhelium terms, is given by those helium atoms whose electrons have opposing spins.

ORTHONIK. Trade name for a high permeability, highly grain-oriented 50% nickel, 50% iron alloy.

ORTHONOL. See **orthonik.**

ORTHONORMAL. Suppose a set of functions of the complex variable z is defined over the range $a \leqq z \leqq b$, so that the members of the set, $f_1(z)$, $f_2(z)$ $\cdots$ are **orthogonal**

$$\int_a^b f_i^*(z) f_j(z) dz = 0 \quad i \neq j.$$

Then presumably

$$\int_a^b f_i^*(z) f_i(z) dz = c_i^2 \neq 0, \text{ a constant.}$$

It is frequently convenient to redefine the functions so that they are **normalized** and take $c_i\phi_i(z) = f_i(z)$, then

$$\int_a^b \phi_i^*(z)\phi_j(z)dz = \delta_{ij}$$

and the functions $\phi_i(z)$ are said to form **an orthonormal set.** For an arbitrary set of functions, $f_i(z)$, conversion to orthonormal functions may be effected by the **Schmidt process.**

If z is real, obvious simplifications in the equations are possible.

ORTHOPOSITRONIUM. The state of **positronium** in which the spins of electron and positron are parallel. The 1s state annihilates into three gamma-rays with a mean life of 1.4×10^{-7} sec.

ORTHORHOMBIC SYSTEM. One of the seven fundamental systems of **crystallography;** in this system the axes are of unequal length, and intersect at right angles.

ORTHOSCOPIC SYSTEM. An optical system corrected for both **distortion** and **spherical aberration.** Also called rectilinear system.

ORTHO-STATE. (1) In diatomic molecules, such as hydrogen molecules, the ortho-state exists when the spin vectors of the two atomic nuclei are in the same direction (i.e., parallel), whereas the **para-state** is the one in which the nuclei are spinning in opposite directions. (2) In **helium** the ortho-state is characterized by a particular mode of coupling of the electron spins. (See **orthohelium.**)

ORTHOTOMIC SYSTEM. An optical system which contains only rays which may be cut at right angles by a properly-constructed surface.

OSBORNE, STIMSON AND JENNINGS METHOD FOR MECHANICAL EQUIVALENT OF HEAT. A semi-adiabatic calorimeter is used, which is surrounded by a shell kept at the same temperature. The calorimeter contains water and water vapor, and the rise in temperature upon the application of a measured amount of electrical energy is determined, as well as the change in the state of water.

OSCILLATING CRYSTAL METHOD. A technique for the **x-ray analysis** of **crystal structure,** in which the specimen is oscillated through an angle of 10–20°, allowing a limited number of reflecting positions to be exposed to the incident x-ray beam.

OSCILLATING CYLINDER METHOD FOR VISCOSITY. The viscosity of a gas or liquid is measured by the damping of the oscillations of a cylinder which is suspended on a torsion fiber inside a stationary cylinder. The space between the cylinders is filled with the gas or liquid under investigation.

OSCILLATING DISC METHOD. See **viscosity, measurement of.**

OSCILLATION. An oscillation is one complete period of vibratory or periodic motion, for example, the whole succession of states that takes place before the motion begins to repeat itself. For example, one oscillation of a pendulum bob is a complete excursion from where it started back to its original position with the *same* velocity (magnitude and direction). The time of one oscillation is called one period and the number of oscillations per second (the reciprocal of the period) is called the frequency. The definition cannot be applied strictly to nonperiodic motions (e.g., see **oscillation, damped harmonic**) In such motions the period is usually taken as the time between successive zeros of the displacement.

OSCILLATION, DAMPED HARMONIC. An oscillation in which there is resistance to the motion. This resistance is opposite to the direction of motion and to a good approximation is proportional to the first power of the velocity. The presence of the resistance leads to a continuous dissipation of the total mechanical energy of motion.

The differential equation of motion for a dissipative oscillatory system with one degree of freedom and no external driving force is

$$m\frac{d^2x}{dt^2} + R\frac{dx}{dt} + fx = 0$$

where m is the mass of particle. R is the **damping coefficient,** f is the **stiffness coefficient.** The solution is of the form

$$x = e^{-\frac{R}{2m}t}\left(Ae^{\sqrt{R^2/4m^2 - f/m}\,t} + Be^{-\sqrt{R^2/4m^2 - f/m}\,t}\right)$$

where A and B are arbitrary constants.

If $\dfrac{R^2}{4m^2} < \dfrac{f}{m}$, oscillations of steadily decreasing amplitude take place with frequency $\nu = \dfrac{1}{2\pi}\sqrt{f/m - R^2/4m^2}$.

If $\dfrac{R^2}{4m^2} = \dfrac{f}{m}$, no oscillations take place and motion is said to be "critically damped."

If $\frac{R^2}{4m^2} > \frac{f}{m}$, no oscillations take place and motion is said to be "overdamped."

(See **dissipative system; dissipation function; logarithmic decrement.**)

OSCILLATION, ELECTRIC. See **electric oscillations and electric waves.**

OSCILLATION, FORCED. The oscillation which results when an external periodic driving force is applied to a system capable of free oscillations (cf. **simple harmonic motion, damped oscillations**). In the one-dimensional case for a dissipative system the differential equation of motion is

$$m\frac{d^2x}{dt^2} + R\frac{dx}{dt} + fx = F_0 \cos 2\pi\nu t.$$

F_0 is the amplitude of driving force; ν is frequency of driving force.

The solution to this equation has two parts, a transient which eventually damps to zero, and a steady state which is the dominant part when the transient diminishes. The steady state solution has the form

$$x = \frac{F_0 \cos (\omega t - \alpha)}{\sqrt{\omega^2 R^2 + (f - m\omega^2)^2}}$$

where $\omega = 2\pi\nu$, $\alpha = \tan^{-1}\frac{R\omega}{f - m\omega^2}$ = phase difference between force and displacement.

Of special interest in forced oscillations is the phenomenon of resonance. Velocity resonance is a state of maximum velocity and occurs when the frequency of the driving force has the value $\nu_0 = \frac{1}{2\pi}\sqrt{\frac{f}{m}}$. ν_0 is called the *resonance frequency*. *Amplitude resonance* is a state of maximum displacement and occurs when the frequency of the driving force has the value $\nu_1 = \frac{1}{2\pi}\sqrt{f/m - R^2/4m^2}$.

When the damping coefficient is small, the amplitude resonance frequency ν_1 and the free oscillation frequency become approximately the same. At the resonance frequency ν_0, the force and velocity are exactly in phase while the force and displacement are 90° out of phase. The word resonance in general usage means amplitude resonance. (See **simple harmonic motion, damped oscillations.**)

OSCILLATION(S), FREE OR NATURAL. (1) **Oscillations** that continue in a circuit or system after the applied force has been removed, the frequency of the oscillations being determined by the parameters in the system or circuit, commonly referred to as shock-excited oscillations. (2) The oscillation of some physical quantity of a body or system when the externally applied forces consist either of those which do no work, or of those which are derivable from a potential that is invariant during the time under consideration, or both. (3) That type of oscillatory motion into which a suitable system not subject to external driving forces is capable of being excited by a displacement from an equilibrium position. (See **harmonic motion, damped.**)

OSCILLATION, FREQUENCY OF. The number of complete **oscillations** of a given system per unit time, commonly symbolized by ν or f. The **frequency** is the reciprocal of the **period**, the time for one complete oscillation. Sometimes the **angular frequency,** symbolized by ω, is used for greater convenience in manipulating trignometric functions The angular frequency has the unit radian per unit time and is equal to $2\pi \times$ frequency.

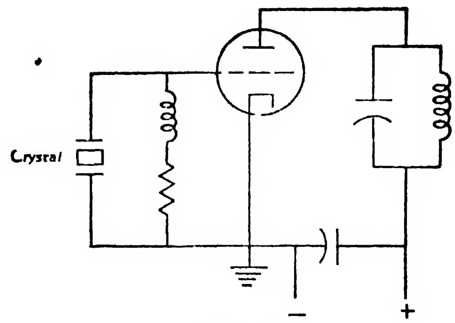
OSCILLATION, MODES OF. In the case of **standing waves** the boundary conditions restrict the possible frequencies of oscillation to a discrete set of values. The whole set constitutes the modes of oscillation of the system. The oscillations of a string clamped at both ends, and the oscillations of sound waves in a closed or open pipe are examples of cases where boundary conditions impose modes.

OSCILLATION(S), PARASITIC. Unintended self-sustaining **oscillations,** or transient impulses.

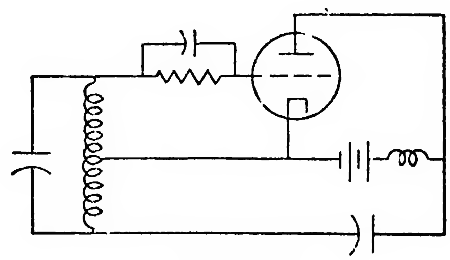
OSCILLATION, STEADY-STATE (VIBRATION). The oscillation of a body or system in which the motion at each point is a periodic quantity. This is frequently a special case of forced oscillation.

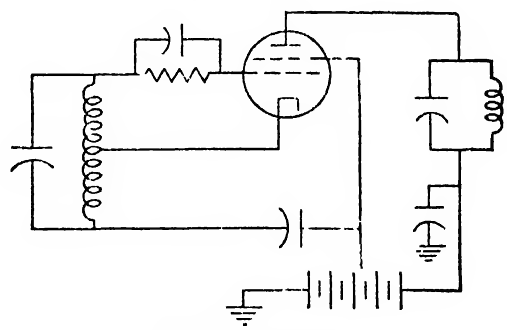
OSCILLATOR. (1) A nonrotating device for producing alternating current, the output frequency of which is determined by the char-

acteristics of the device. The oscillator is the heart of the radio **transmitter** since it generates the high-frequency carrier signal essential for this type communication. The early oscillators used in radio consisted of inductance-capacitance circuits to which a surge of electrical energy was applied by the breakdown of a spark gap or an arc. This energy then surged back and forth between the inductance and capacitance until it was all dissipated as radiation and as circuit losses. This type oscillator produced damped oscillations and is no longer used. Modern oscillators use **vacuum tubes** in various circuit arrangements. Since the ordinary vacuum tube is inherently an amplifying device, it can be used as an oscillator by feeding back some of the output energy to the **grid** so the tube effectively drives itself. The various oscillator circuits in common use are utilizations of different means of doing this. For stable frequency characteristics crystal-controlled oscillators are used in most stations. In these a quartz **crystal** is connected in the grid circuit of the vacuum tube so the voltages produced by the crystal when it vibrates mechanically control the grid and hence the plate output of the tube. Enough energy is fed back, usually through the grid-plate capacitance of the tube, to keep the crystal in a steady state of vibration. Because of the high frequency stability of the mechanical vibrations, the output frequency of the circuit is remarkably stable, in some cases where extreme care is exercised amounting to 1 part in 20,000,000. In modern broadcast stations the crystals maintain the frequency accurately to 2 or 3 cycles. Where continuously adjustable frequency output is needed some type of self-controlled oscillator is needed. The Hartley, shown in the figure, is one of the simplest. The energy is fed back from the plate to the grid circuit through the inductive coupling of the two sections of the coil. The frequency is determined by the inductance and capacitance values in the tuned circuit. A somewhat more complicated but more stable variable circuit is the electron-coupled oscillator shown at (c). This uses a tetrode or pentode tube, utilizing the screen as the plate of an oscillator whose output is coupled by the electron stream in the tube to the main plate circuit. The one shown employs the Hartley circuit. At very high frequencies the oscillator frequency is often controlled by a resonant transmission **line**. At **ultra high frequencies** special tubes and types of circuits must be used. In these the frequency is largely determined by the transit time of the electrons in the tube. (2) Any system which provides for the storage of energy in two



(a) Crystal


(b) Hartley


(c) Electron-coupled

forms (e.g., kinetic and potential, electric and magnetic) and which therefore can undergo processes in which some quantity varies periodically with time. The quantity may be the displacement or the velocity of a mass in a mechanical oscillator, the charge on a capacitor in an electrical oscillator, etc.

OSCILLATOR, ANHARMONIC. A mechanical system with one degree of freedom which, when displaced from equilibrium, is subject to a restoring force corresponding to a superposition of first and higher powers of

the displacement. A simple example of an anharmonic oscillator has the equation of motion

$$m\frac{d^2x}{dt^2} + k_1x + k_2x^2 = 0.$$

The vibrations of the human ear drum may be described by an equation of this form, which means physically that the restoring force is not symmetrical about the equilibrium position of the oscillator. The equation is mathematically non-linear (because of the presence of the square term k_2x^2) and leads to a solution involving harmonics of the fundamental oscillation frequency (if the anharmonic term k_2x^2 is always small compared with the harmonic term k_1x).

OSCILLATOR, BALANCED. An **oscillator** in which the impedance centers of the **tank circuits** are at ground potential, and the voltages between either end and their centers are equal in magnitude and opposite in phase

OSCILLATOR, BARKHAUSEN-KURZ. An **oscillator** of the retarding-field type in which the frequency of oscillation depends solely upon the **electron-transit time** within the tube.

OSCILLATOR, BEAT-FREQUENCY. See **beat-frequency oscillator.**

OSCILLATOR, BEATING. See **beat-frequency oscillator.**

OSCILLATOR, BLOCKING. A transformer-coupled, feedback oscillator (see **oscillator, feedback**) in which plate current flows for only one-half cycle before the oscillation is halted due to blocking of the grid. The oscillation then ceases for a period determined by the time required for the grid to become unblocked The length of the current pulse is determined by the transformer resonance. The period of the pulse is determined by relaxation oscillator principles. (See **oscillator, relaxation.**)

If the grid should not block after the first half-cycle of current and oscillation continue for one or more cycles before being disrupted, the oscillator becomes known as a squegging oscillator. (See **oscillator, squegging.**)

OSCILLATOR, CLAMP. A series-tuned Colpitts oscillator noted for its low drift characteristics.

OSCILLATOR, COHERENT. An oscillator which has a fixed phase relationship to some other (reference) oscillator.

OSCILLATOR, COLPITTS. An **oscillator** in which the parallel-tuned **tank circuit** is connected between grid and plate, with the tank capacitance containing two voltage-dividing capacitors in series, with their common connection at cathode potential and the necessary **feedback voltage** being obtained across the grid-cathode capacitor. When the two voltage-dividing capacitances are the plate-to-cathode and the grid-to-cathode capacitances of the tube, the circuit is known as the ultra-audion oscillator.

OSCILLATOR, COUPLED (MECHANICAL). A system with two or more components coupled by forces which can be considered either exactly or approximately as harmonic. The resultant motion of each component when the system is displaced from its equilibrium position can be considered as a linear superposition of simple harmonic oscillations with characteristic frequencies known as **normal frequencies.** For a non-degenerate non-dissipative coupled system of n particles each having one degree of freedom, there will exist n normal frequencies. It is theoretically possible by the correct choice of initial conditions to set a coupled system into oscillation so that all the particles vibrate with only one normal frequency. Such a vibration is called a normal mode of vibration. For the n particle system there will exist n normal modes and n **normal coordinates.** A normal coordinate vibrates harmonically with a single normal frequency and can be found by a transformation of the actual displacement coordinates which describe the individual motion of each particle.

OSCILLATOR, CRYSTAL. A generator of alternating-current energy, the frequency of which is determined by the mechanical properties of a **piezoelectric crystal.** (See discussion under **oscillator.**)

OSCILLATOR, DAMPED LINEAR. A linear oscillator subject to a damping coefficient. (See **oscillator, linear; oscillation, damped harmonic.**)

OSCILLATOR, DOW ELECTRON-COUPLED. See **oscillator, electron-coupled.**

OSCILLATOR, DYNATRON. A negative-resistance **oscillator** with negative resistance derived between plate and cathode of a **screen-grid tube** operating such that secondary electrons produced at the plate are attracted to the higher-potential screen grid.

OSCILLATOR, ELECTRON - COUPLED. An **oscillator** employing a **multigrid tube** with the cathode and two grids operating in any conventional manner as an oscillator, and in which the plate-circuit load is coupled to the oscillator through the electron stream. (See discussion under **oscillator.**)

OSCILLATOR, FEEDBACK. An oscillating circuit, including an **amplifier,** in which the output is coupled in phase with the input, the oscillation being maintained at a frequency determined by the parameters of the **amplifier** and the feedback circuits such as L-C, R-C, and other frequency-selective elements.

OSCILLATOR, GILL-MORRELL. An oscillator of the retarding-field type (see **oscillator, retarding-field**) in which the frequency of oscillation is dependent not only on **electron-transit time** within the tube, but also on associated circuit parameters.

OSCILLATOR, HARMONIC. (See also **oscillation, damped; oscillation, forced; oscillation, anharmonic.**) A mechanical system with one degree of freedom which when displaced from equilibrium, is subject to a restoring force varying directly as the displacement. If the effective mass is m, the stiffness is k, and the displacement is x, the differential equation of motion of the harmonic oscillator is

$$m\frac{d^2x}{dt^2} + kx = 0$$

leading to solution

$$x = Ae^{i(2\pi\nu t+B)}$$

where $\nu = \frac{1}{2}\pi\sqrt{k/m}$ is the **frequency,** A is the **amplitude** and B is the initial phase, or epoch. This system is undamped and performs simple harmonic motion. Note that x need not be a linear displacement but may be an angle. Harmonic oscillations in different directions in a plane may be superposed and the result is often referred to as a two-dimensional harmonic oscillator. The motion of the resultant system is, however, not necessarily periodic and the use of the name therefore somewhat questionable.

The wave mechanical solution of the problem analogous to that of the classical harmonic oscillator plays an important role in atomic and molecular physics. If a particle of mass m is constrained to linear motion with its potential energy V being proportional to the square of the displacement x from some equilibrium position, the **Schrödinger equation** is

$$\left\{\frac{d^2}{dx^2} + \frac{m}{\hbar^2}\left(E - \frac{1}{2}kx^2\right)\right\}\psi = 0$$

where $\hbar$ is the Dirac h, k is a constant, and E is the energy of the particle. This equation has solutions only for discrete **eigenvalues (1)** of E, these being

$$E_n = \hbar\sqrt{k/m}\,(n + \tfrac{1}{2})$$

where n is an integer $(0, 1, 2 \cdots)$. The **eigenfunctions** are

$$\psi_n = e^{-\frac{1}{2}\alpha q^2}H_n(x)$$

where $H_n(x)$ is a **Hermite polynomial** and $\alpha = \sqrt{km/\hbar}$. As the expression for E_n shows, the wave mechanical harmonic oscillator differs from the classical in that only discrete, equally-spaced energy levels are possible and that the lowest state has an energy $(\hbar/2)\sqrt{k/m}$. This leads to the concept of **zero point energy.**

OSCILLATOR HARMONIC INTERFERENCE. **Interference** encountered in **superheterodyne receivers** caused when harmonics of the local oscillator heterodyne with some undesired **carrier** to produce the correct **intermediate frequency.**

OSCILLATOR, HARTLEY. An **oscillator** in which the parallel-tuned **tank circuit** is connected between grid and plate, the inductive element of the tank having an intermediate tap at cathode potential, and the necessary **feedback voltage** obtained across the grid-cathode portion of the inductor. (See discussion under **oscillator.**)

OSCILLATOR, HETERODYNE. See **heterodyne oscillator.**

OSCILLATOR, LINEAR. An oscillator of the simple harmonic type is referred to as lin-

ear because mathematically it has a differential equation of the linear type, i.e., there are no terms of higher than first degree in the dependent variable (the displacement). The linear type of differential equation possesses certain general properties which are valuable in quickly expressing the solution of such an equation. Fortunately, many types of oscillatory motion both macro-scale and micro-scale in which the amplitude is small can be approximated by the linear oscillator. In certain cases such as the human eardrum, the restoring force is not symmetrical about the equilibrium position, and the resulting differential equation contains terms in the independent variable of higher than the first degree. Such an oscillator is said to be anharmonic and the differential equation is said to be non-linear.

OSCILLATOR, LINEAR HARMONIC. See **oscillator, linear.**

OSCILLATOR, LINEAR TIME-BASE OF C.R.O. An oscillator whose output waveform is a saw-tooth pattern.

OSCILLATOR, LOAD INDEX OF. The ratio of the total effective load conductance to which the **oscillator** is subjected to the load conductance which will cause oscillations to cease.

OSCILLATOR, LOCAL. An **oscillator** whose output is mixed with a wave for **frequency conversion.**

OSCILLATOR, LOCKED. An **oscillator** which is synchronized with some other oscillator.

OSCILLATOR, MAGNETRON. An **electron tube** in which electrons are accelerated by a radial electric field between the cathode and one or more anodes, and by an axial magnetic field that provides a high-energy electron-stream to excite the **tank circuits.**

OSCILLATOR, MAGNETOSTRICTION. An **oscillator** with the plate circuit inductively coupled to the **grid circuit** through a **magnetostrictive** element, the frequency of oscillation being determined by the magneto-mechanical characteristics of the coupling element.

OSCILLATOR, MASTER. An **oscillator** so arranged as to establish the **carrier frequency** of the output of an **amplifier.**

OSCILLATOR, MEACHAN BRIDGE. A very stable type of feedback oscillator (see **oscillator, feedback**) in which the output of the **amplifier** is coupled to the input through a four-arm bridge. One arm of the bridge contains a **piezoelectric crystal** for frequency control, while another arm contains a thermally-sensitive **resistor** for amplitude control. The remaining arms are fixed resistors. This circuit is used in the very constant frequency oscillators of the Bell system, Bureau of Standards and the Greenwich Observatory.

OSCILLATOR, MECHANICAL. A system of components capable of **oscillatory motion.** It is also possible to have oscillations in an electrical circuit with components analogous to those in mechanical systems. (See **harmonic oscillator; electrical analogies in mechanical systems.**)

OSCILLATOR, MEISSNER. An **oscillator** in which the **grid circuit** and **plate circuit** are inductively coupled through an independent **tank circuit** which determines the frequency.

OSCILLATOR, NEGATIVE-RESISTANCE. An **oscillator** produced by connecting a parallel-tuned resonant circuit to a two-terminal negative-resistance device. (One in which an increase in voltage results in a decrease in current.) Dynatron and transitron oscillators are examples. (See **oscillator, dynatron** and **oscillator, transitron.**)

OSCILLATOR, NEGATIVE-TRANSCONDUCTANCE. An electron-tube **oscillator** in which the output of the tube is coupled back to the input without phase shift, the phase condition for oscillation being satisfied by the negative **transconductance** of the tube.

OSCILLATOR PADDER. An adjustable **capacitor** employed in conjunction with the tuning capacitor of a local **oscillator** to assure satisfactory tracking.

OSCILLATOR, PHASE-SHIFT. An **oscillator** produced by connecting any **network** having a **phase shift** of an odd multiple of 180° (per stage) at the frequency of oscillation, between the output and the input of an amplifier. When the phase shift is obtained by resistance-capacitance elements, the circuit is an R-C phase-shift oscillator.

OSCILLATOR, PIERCE. An **oscillator** in which a **piezoelectric crystal** is connected between the plate and the grid of a tube, in what is basically a Colpitts oscillator (see **oscillator, Colpitts**) with voltage division provided by the grid-to-cathode and the plate-to-cathode capacitances of the circuit

OSCILLATOR, PIEZOELECTRIC. An oscillator employing a piezoelectric crystal (see **piezoelectric effect, direct**) in its tuned circuit in place of conventional inductive and capacitative elements.

OSCILLATOR, PULSED. An **oscillator** which generates a carrier-frequency **pulse** or a train of carrier-frequency pulses. These carrier-frequency pulses may occur as the result of self-generated or externally-applied pulses.

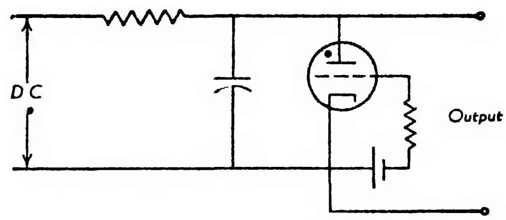
OSCILLATOR, PUSH-PULL. A balanced **oscillator** employing two similar tubes in phase opposition

OSCILLATOR, R-C. An **oscillator** in which the frequency is determined by resistance-capacitance elements

OSCILLATOR, RE-ENTRANT. A form of oscillator using three coaxial-line resonators which are effectively connected in series at the end of the grid cylinder. Feedback coupling is obtained through the ends of the grid-cathode line and the grid-plate line, which terminate in a common cathode-plate line. The frequency stability of this oscillator is in general inferior to that of a two-resonator oscillator with probe or loop coupling

OSCILLATOR, REFLEX OR REPELLER TYPE OSCILLATOR. See **klystron, reflex.**

OSCILLATOR, RELAXATION. An **oscillator** whose fundamental frequency is determined by the time of charging or discharging of a capacitor or inductor through a resistor, producing wave forms which may be rectangular or sawtooth. These oscillators have very distorted wave shapes, giving various outputs such as square waves, trapezoidal waves, triangular waves and pulses of very short duration. These distorted waves have made them ideal for many control and triggering purposes in more elaborate electronic circuits. The relaxation oscillator may be easily synchronized with another oscillator or other source of voltage by injecting some of the other voltage into the relaxation circuit at the proper point. A simple, but widely used, relaxation oscillator is shown in the figure.



Relaxation Oscillator

Output

Here the condenser is charged through the resistance until the voltage across the thyratron reaches the breakdown value when it breaks down and discharges the condenser very rapidly. The process is then repeated and the resultant voltage output is as shown.

OSCILLATOR, RESONANT-LINE. An **oscillator** in which one or more sections of **transmission line** are employed as **tanks.**

OSCILLATOR, RETARDING-FIELD (POSITIVE-GRID). An **oscillator** employing an electron tube in which the electrons oscillate back and forth through a **grid** maintained positive with respect to the cathode and the plate. The frequency depends on the **electron-transit time** and may also be a function of the associated circuit parameters The field in the region of the grid exerts a retarding effect which draws electrons back after passing through it in either direction. Barkhausen-Kurz and Gill-Morrell oscillators are examples. (See **oscillator, Barkhausen-Kurz** and **oscillator, Gill-Morrell.**)

OSCILLATOR, RING. An arrangement of two or more pairs of tubes operating as push-pull oscillators (see **oscillator, push-pull**) around a ring, usually with alternate successive pairs of grids and plates connected to **tank circuits.** Adjacent tubes around the ring operate in phase opposition. The load is supplied by coupling to the plate circuits.

OSCILLATOR STARTING TIME, PULSED. See **pulsed oscillator starting-time.**

OSCILLATOR, SQUEGGING. An **oscillator** whose amplitude builds up over several cycles of the oscillations, and then decays again to zero, due to a blocking action on the grid of some tube The period between these oscillations is determined by relaxation oscillator action (See **oscillator, relaxation.**)

OSCILLATOR, TRANSITRON. A negative-transconductance **oscillator** employing a **screen-grid tube** with negative **transconductance** produced by a retarding field between the negative screen grid and the control grid which serves as the anode

OSCILLATOR, TRI-TET. A crystal-controlled, electron-coupled **oscillator.** Since the output current is rich in harmonics, it is frequently used as a **frequency multiplier.**

OSCILLATOR, TUNED-GRID. An **oscillator** with frequency determined by a parallel-tuned **tank** in the **grid circuit** coupled to the plate to provide the required **feedback.**

OSCILLATOR, TUNED-GRID, TUNED-PLATE. An **oscillator** having parallel-tuned **tanks** in both plate and grid circuits, the necessary **feedback** being obtained by the plate-to-grid interelectrode capacitance

OSCILLATOR, TUNED-PLATE. An **oscillator** with frequency determined by a parallel-tuned **tank** in the plate circuit coupled to the **grid** to provide the required **feedback.**

OSCILLATOR, ULTRAAUDION REGENERATIVE. A form of Colpitts oscillator (obsolete).

OSCILLATOR, VELOCITY-MODULATED. An **electron-tube** structure in which the velocity of an electron stream is varied (velocity-modulated) in passing through a resonant cavity called a **buncher.** Energy is extracted from the bunched electron stream at a higher energy level in passing through a second cavity resonator called the catcher Oscillations are sustained by coupling energy from the **catcher** cavity back to the buncher cavity.

OSCILLATOR, WIEN BRIDGE. A phase-shift, feedback oscillator which employs a **Wien bridge circuit** as the frequency-determining element.

OSCILLIGHT. The name sometimes applied to a **kinescope.**

OSCILLOGRAM. The record produced by an **oscillograph.** (See **oscilloscope.**)

OSCILLOGRAPH. (1) In older usage, a device for producing a written or visible curve representing variable current, voltage or other electrical quantities. In one such device, electric oscillations in a circuit caused electromagnetic vibrations of a filament bearing a mirror which reflected a light-beam onto a moving photographic film Other such devices used **cathode-ray tubes.** These devices are more generally known today as **oscilloscopes,** even when they produce a record.

OSCILLOGRAPH GALVANOMETER. See **galvanometer, oscillograph.**

OSCILLOSCOPE. The name generally applied to a cathode-ray device (e g , tube) used to produce a visible pattern, which is the graphical representation of electrical signals, by variations of the position of the focused spot or spots in accordance with these signals The oscilloscope also may contain associated amplifiers, sweep generators, and power supplies (See **kinescope;** also **tube, cathode-ray.**)

OSCILLOSCOPE, CATHODE-RAY. An instrument wherein an applied signal causes the deflection of the electron beam in a **cathode-ray tube,** thus producing a visible trace on the phosphor screen of the tube.

OSCILLOSCOPE, DEFLECTION POLARITY OF. The relationship between the direction of displacement and the polarity of the applied signal wave in an **oscilloscope.**

OSCULATION, POINT OF. A singular point on a curve where the curve recedes from the tangent in both directions from the point of tangency. The conditions which must be met are the same as those for **cusps.**

OSMIUM. Metallic element Symbol Os. Atomic number 76.

OSMOMETER. An instrument used to measure **osmotic pressure.**

OSMOSIS. The passage of a fluid through a semipermeable membrane, due to **osmotic pressure.**

OSMOTIC COEFFICIENT. A factor introduced into equations for nonideal solutions to correct for their departure from ideal behavior, as in the equation:

$$\mu = \mu_x^0 + gRT \ln x_1,$$

in which μ is the **chemical potential,** μ_x^0 is a constant, representing a standard value of the chemical potential, R is the **gas constant,** T the absolute temperature, x_1 is the **mole fraction** of solvent, and g is the osmotic coefficient.

OSMOTIC PRESSURE. Pressure that develops when a pure solvent is separated from a solution by a semipermeable membrane which allows only the solvent molecules to pass through it. The osmotic pressure of the solution is then the excess pressure which must be applied to the solution so as to prevent the passage into it of the solvent through the semipermeable membrane.

OSMOTIC PRESSURE, METHODS OF MEASUREMENT. In the Berkeley and Hartley method, a porous tube with a semipermeable membrane such as copper ferrocyanide deposited near the outer wall, and a capillary tube attached at one end contains the pure solvent. The solution surrounds the tube and is enclosed in a metal vessel to which a pressure may be applied which is just sufficient to prevent the flow of solvent into the solution. Berkeley and Hartley also developed a dynamic method for measuring osmotic pressure. For the **Frazer method,** see that entry. Simple osmometers have also been developed by Adair particularly for aqueous colloidal solutions. A thimble-type collodion membrane is attached to a capillary tube and contains the solution. When equilibrium is established the difference in level inside and outside the capillary is measured. Capillary corrections are made. For organic solvents a dynamic type **osmometer** may be used. A membrane of large surface area is clamped between two half cells and attached to each half cell is a fine capillary observation tube. With such an apparatus, equilibrium is rapidly established between solution and solvent contained in the half cells. The volume of the half-cell may be small (about 20 cm^3). The level of the solvent is usually arranged to be a little below the equilibrium position, and the height of the solvent in the capillary as a function of time is measured. This procedure is repeated with the level of the solvent just above the equilibrium position. A plot is then made of the half-sum of these readings.

OSMOTIC PRESSURE, RELATION TO LOWERING OF FREEZING POINT AND ELEVATION OF BOILING POINT OF SOLUTIONS. The relation between osmotic pressure and lowering of the freezing point and the elevation of the boiling point may be expressed by the relation.

$$\Pi = \frac{LT}{\bar{v}T_0^2}\,\Delta T$$

where L is the molar heat of fusion or of vaporization of the solvent, T the temperature at which the osmotic pressure is measured, T_0 the freezing point or the boiling point of the solvent, $\bar{v}$, the **partial molar volume** of the solvent, and Π, the osmotic pressure.

OSMOTIC PRESSURE, RELATION TO LOWERING OF VAPOR PRESSURE OF SOLUTIONS.

$$\Pi = \frac{RT}{\bar{v}} \ln \frac{p_0}{p}$$

or

$$\Pi = -\frac{RT}{\bar{v}} \ln x_0 = -\frac{RT}{\bar{v}} \ln (1 - x).$$

For dilute solutions

$$\Pi = cRT$$

where Π is the osmotic pressure, $\bar{v}$ the partial molar volume of the solvent in the solution, p_0 the vapor pressure of pure solvent, p the partial vapor pressure of the solvent in equilibrium with the solution, x_0 the mole fraction of the solvent, x the mole fraction of the solute, c the concentration of the solution in moles per liter, R, the **gas constant,** and T, the absolute temperature.

OSMOTIC PRESSURE, THEORIES OF. Because of the similarity in the relations for **osmotic pressure** in dilute solutions and the equation for an ideal gas, van't Hoff proposed his bombardment theory in which osmotic pressure is considered in terms of collisions of solute molecules on the semipermeable membrane. This theory has a number of objections and has now been discarded. Other theories have also been put forward involving solvent bombardment on the semipermeable

membrane, and vapor pressure effects. For example, osmotic pressure has been considered as the negative pressure which must be applied to the solvent to reduce its vapor pressure to that of the solution. It is, however, more profitable to interpret osmotic pressure using thermodynamic relations, such as the entropy of dilution

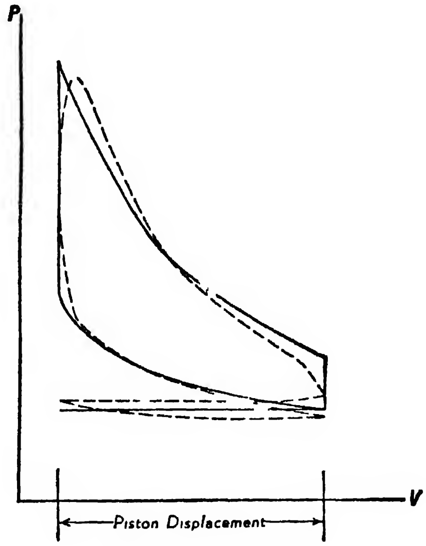
OSOPHONE. A receiver or headphone which transfers sound vibrations directly to the bone of the head.

OSTWALD DILUTION LAW. See **dilution law, Ostwald.**

OTTO CYCLE. The possibilities of an **internal combustion engine** which would operate on the **four-stroke cycle** were analyzed in the nineteenth century by de Rochas The action of an engine, which was at that time described only, is in all fundamental respects the same as that used today Shortly after this internal combustion engine analysis was made, the German Otto built an engine which operated on the four-stroke cycle, and which has come, since, to be called the Otto cycle The Otto cycle is carried out by a series of operations, namely, and in order:

(1) Suction during outward stroke of the piston
(2) Compression during inward stroke of the piston
(3) Expansion during outward stroke of the piston following ignition at inward dead center
(4) Exhaust during inward stroke of the piston

Although the first engines built by the Otto works were four-stroke cycle (**four-cycle**) engines, the Otto engine can be adapted to a two-stroke cycle (**two-cycle**) An engine which operates on the Otto cycle has considerable clearance volume (when the piston is on dead center) into which the air and fuel drawn in on the suction stroke are compressed. As the piston pauses instantaneously on dead center position, the charge is **ignited** and **combustion** of the charge occurs at constant volume. The heat added by this combustion greatly increases the pressure During the expansion stroke, this pressure is lowered, and a considerable amount of the heat is taken from the gas to be converted into work At the end of expansion, the pressure is dropped to the exhaust point, and the exhaust gases are pushed out of the cylinder, which is thus cleared for the next suction stroke. In the figure which illustrates the Otto cycle in the-



Otto cycle diagram

ory and in practice, the cycle is shown on the pressure-volume plane The ideal cycle is shown solid, and departures from it, made by actual cycles, are shown dotted The ideal four-stroke cycle is made up of two isovolumetric changes, one representing the combustion of fuel at constant volume, the other the rejection of heat to the exhaust at constant volume, and two **adiabatic** changes, one representing the compression of the charge, the other the power stroke Finally, there are two coincident constant pressure changes, representing the ideal exhaust and suction strokes An actual working cycle will not have quite the same processes

OUDEMAN, LAW OF. (Law of Landolt-Oudeman) The **molecular rotations** of the salts of **optically active** acids or bases always tend to a definite limiting value as the concentration of the solution diminishes; e g , the soluble salts of α-bromosulfocamphoric acid show identical molecular rotations in hundredth normal solutions.

OUNCE. A unit of **mass** in the avoirdupois, apothecaries', and troy systems. The apothecaries' and troy ounces are identical.

1 avoirdupois ounce = 28.3495 grams
1 avoirdupois ounce = 437.5 grains

1 troy or apothecaries' ounce	=	31.1035 grams
1 troy or apothecaries' ounce	=	
	=	480 grains.

OUTGASSING. The evacuation process during the manufacture of **vacuum tubes**, for removal of as much air as possible by heating all parts of the tube to a high temperature.

OUTER BREMSSTRAHLUNG. See **bremsstrahlung.**

OUTPUT ADMITTANCE, TRANSISTOR. See **transistor parameter h_{22}.**

OUTPUT CAPACITANCE (OF AN *n*-TERMINAL ELECTRON TUBE). See **capacitance, output (of an *n*-terminal electron tube).**

OUTPUT EQUIPMENT. The equipment used for obtaining **information** from a **computer.**

OUTPUT IMPEDANCE. The impedance presented by the **transducer** to a load

OUTPUT, INSTANTANEOUS POWER. The rate at which energy is delivered to a **load** at a particular instant.

OUTPUT METER. An **instrument** used for measuring the output of audio **amplifiers.** It consists of a resistor coupled to the amplifier through an impedance-matching **transformer** and a rectifier voltmeter connected across the resistor. The voltmeter is usually calibrated so it indicates the watts dissipated in the resistor either directly in watts or in **decibels** above some reference value.

OUTPUT, PEAK POWER. The output power averaged over the radio-frequency cycle having the maximum peak value which can occur under any combination of signals transmitted.

OUTPUT WINDINGS. Of a **saturable reactor,** those windings other than **feedback** associated with the load and through which power is delivered to the load. (See **gate circuit.**)

OUTSCRIBER. An output **transcriber.**

OVAL WINDOW. An opening from the cavity of the inner ear to the middle ear. Motion from the middle ear is carried through the oval window by the action of the stirrup bone.

OVERCAST. A term descriptive of the sky when it is more than $^9/_{10}$ covered with clouds. Viewed from on top (aircraft view) it is said to be undercast.

OVERFLOW. (1) The condition which arises when the result of an arithmetic operation exceeds the capacity of the number representation in a **digital computer.** (2) The carry digit arising from this condition.

OVERGROWTH. The growth of a crystal of one substance on the surface of a crystal of another. The conditions for this are rather less stringent than for the formation of a **mixed crystal,** but certain relations between the radii and interatomic distances of the two compounds may be preferable.

OVERHEATING. Raising the temperature of a liquid above its boiling point. Drops of water in oil may be overheated to 140°C at atmospheric pressure without vaporizing.

OVERLAP. (1) In some **magnetic amplifier** and **rectifier** circuits, the undesirable flow of current for a period after the supply voltage has gone to zero (and perhaps reversed) caused by energy stored in some circuit inductance. (2) In a magnetic amplifier, the simultaneous conduction of the half wave elements during certain intervals of supply voltage cycle.

OVERLAPPING. The coincidence of the long-wave end of a **diffraction** or **interference** spectrum with the short-wave end of the spectrum of the next higher order; a source of confusion in spectroscopy.

OVERLOAD CAPACITY. The current, voltage, or power level beyond which permanent damage occurs to the device considered This is usually higher than the rated load capacity.

OVERLOAD LEVEL. The overload level of a system, component, etc., is that level at which operation ceases to be satisfactory as a result of signal distortion, overheating, damage, etc. In electroacoustics the overload level is most frequently set by signal distortion.

OVERSCANNING. Deflection of the beam of a **cathode-ray tube** over an angle larger

than that which subtends the useful screen area.

OVERSHOOT DISTORTION. See **overthrow distortion.**

OVERTHROW DISTORTION. An excessive signal condition in **facsimile.**

OVERTONE. (1a) A physical component of a complex sound having a frequency higher than that of the basic frequency (1b) A component of a complex tone having a pitch higher than that of the fundamental pitch (1c) The term "overtone" has frequently been used in place of **"harmonic,"** the nth harmonic being called the $(n - 1)$st overtone There is, however, ambiguity sometimes in the numbering of components of a complex sound when the word overtone is employed Moreover, the word "tone" has many different meanings so that it is preferable to employ terms which do not involve "tone" wherever possible

(2) In a mechanical vibrating system with a set of normal modes of oscillation (for example, a vibrating string or organ pipe) an overtone is a mode of frequency higher than the **fundamental.** The first overtone is the mode of frequency next higher than the fundamental, etc. (See **harmonic.**)

OVERTONE BAND, FIRST. See **band, first overtone.**

OVERTONE BAND, SECOND. See **band, second overtone.**

OVERVOLTAGE. (1) The excess of observed **decomposition voltage** of an aqueous electrolyte over the theoretical reversible decomposition voltage (2) In radiation counter tubes, the amount by which the applied voltage exceeds the **Geiger-Mueller threshold.**

OVERVOLTAGE, BUBBLE. The **overvoltage** associated with visible evolution of gas, e g, hydrogen bubbles at the cathode.

OWEN BRIDGE. See **bridge, Owen.**

OXIDATION POTENTIAL. The potential drop involved in the **oxidation** (i e, ionization) of a neutral atom to a cation, of an anion to a neutral atom, or of an ion to a more highly charged state (e g ferrous to ferric)

OXYGEN. Gaseous element Symbol O Atomic number 8.

P

P. (1) Pressure (P or p), total pressure (P), vapor pressure (p), static pressure (P_0), varying pressure (p), critical pressure (p_c), osmotic pressure (p, but Π is preferred). (2) Power (P), plate power (P_p), input power (P_i), output power (P_o), average power (P), radiant power or flux (P). (3) Electric polarization (**P**), polarization, surface or strength of double layer ($\mathbf{P}_s$), partial potential coefficient (p). (4) Electric moment (**p**) (5) Generalized momentum (p). (6) Probability (P). (7) Phosphorus (P). (8) Amplitude of simple harmonic sound pressure (P). (9) Distance from principal plane of a lens system to principal plane of a unit (p_u) (10) In spectroscopy, part of band structure (p). (11) Type of electron with an azimuthal quantum number of 1 (p) (12) Spectral term symbol for L-value of 1 (P) (13) Absolute value of vibronic angular momentum of polyatomic molecule (P), in cases of electron spin zero or loosely-coupled, K should be used (14) Proton (p)

P-A. Abbreviation for public address.

P-BRANCH. See **Fortrat parabola.**

P-ELECTRON. An electron characterized by having a principal quantum number of 6

P-SHELL. The collection of electrons characterized by the principal quantum number six. The P-shell is started with the element cesium (atomic number = 55), which has one electron in its P-shell, and the P-shell is not completed, as far as is known, even with the transuranic element of atomic number 101 (mendelevium)

***P*-SPACE.** The same as **momentum space.** P is the symbol often used for **momentum,** or its analogue, **crystal momentum.**

***p-n* HOOK.** A current multiplying device in certain types of **transistor,** whereby a thin region of p-type material is sandwiched between regions of n-type material in such a way as to create a potential "hook," where **holes** are trapped and greatly enhance the flow of electrons.

***p-n* JUNCTION.** The boundary surface between p-type and n-type semiconducting material, produced by varying the impurities during the growth of a single crystal from the melt. Such junctions have strong rectifying properties, the forward current being obtained when p is positive to n. This is readily explained on an **energy band** picture, and is of great importance in the theory and application of **transistors.**

P-TYPE SEMICONDUCTOR. A **semiconducting** material where the current is carried largely by positively-charged **holes,** due to the presence of **acceptor impurities.**

PACKAGED MAGNETRON. See **magnetron, packaged.**

PACKING. The gathering or compression of material or material particles into a relatively confined space.

PACKING FRACTION. The ratio of the **mass defect** to the **mass number** of a nuclide. The packing fraction is related to the binding energy (see **binding energy, nuclear**) through the **mass-energy relation.**

PACKING, NUCLEAR. The concentration of particles within the **nucleus** of an **atom.**

PAD. A fixed **attenuator.**

PADDER. See **oscillator, padder.**

PAIR PRODUCTION. The conversion of a **photon** into an **electron** and a **positron** when the photon traverses a strong electric field, such as that surrounding a nucleus or an electron. The electric charge is conserved, since the electron and positron have charges of equal magnitude and opposite sign. Of the energy $h\nu$ of the photon, a part, $2m_ec^2$, is accounted for by the energy equivalent of the rest mass of the resulting electron-positron pair. If the electric field traversed is that of a nucleus, the quantity $2m_ec^2$ is approximately

the **threshold energy**; the excess, $h\nu - 2m_ec^2$, then appears as the kinetic energies of the electron and positron. If the electric field traversed is that of an electron, this electron itself acquires large kinetic energy and the threshold energy is then precisely $4m_ec^2$. Pair production is one of three distinct processes by which a photon can effect the emission of an electron from matter, the other two processes being the **photoelectric effect** and the **Compton effect.**

PAIR-PRODUCTION ABSORPTION. Absorption of photons, such as γ-rays, in the process of **pair production.**

PAIRED ECHO. A method of analyzing the effects of **phase distortion,** which represents the presence of a non-ideal, phase characteristic by two small **echo signals.**

PAIRING. In television, an effect in which the lines of one **field** do not fall exactly between the lines of the next field. When the effect is pronounced, the lines of the two fields fall directly over each other, effectively reducing the **vertical definition** by half.

PALLADIUM. Metallic element. Symbol Pd. Atomic number 46.

PANCHROMATIC. As applied to photographic emulsions, panchromatic means sensitive to all visible radiation, but not necessarily equally sensitive to all different visible wavelengths.

PANETH RULE. **Adsorption** of **radio-elements** is promoted by formation of an insoluble compound with the adsorbing substance, especially when the radio-element is present in a negative radical.

PANORAMIC RECEIVER. See **receiver, panoramic.**

PAPPUS, THEOREMS OF. Theorems relating **centroids** of curves and areas and volumes of revolution. (1) When a plane curve rotates about an axis in its own plane which does not intersect it, the area of the generated surface of revolution is equal to the product of the length of curve by the length of path of its centroid. (2) When a plane area rotates about an axis in its own plane which does not intersect it, the volume generated is equal to the product of the area by the length of path of its centroid.

PARA-. A prefix used to distinguish between isomers or nearly related compounds. Specifically, the prefix has been used to designate, in the case of gaseous elements having diatomic molecules, the form in which nuclei have anti-parallel spins, as distinguished from the **ortho-state,** in which the two nuclei have parallel spins. Para-molecules have even rotational levels in the ground state, whereas ortho-molecules have odd rotational levels. The two states are present in varying proportions, depending on the temperature, as exemplified by ortho- and para-states of hydrogen. However in **helium** the ortho- and para-states are characterized by a particular mode of coupling of electron spins. (See **orthohelium.**)

PARABOLA. A **conic section** obtained by a cutting plane parallel to an element of a right circular **conical surface.** It is the locus of a point which moves so that its distance from the **directrix** equals its distance from the **focus,** thus the **eccentricity** is unity.

The standard equation in rectangular Cartesian coordinates is

$$y^2 = 2px.$$

The coordinates of its focus are $x = p/2$, $y = 0$ and its directrix is parallel to the Y-axis at $x = -p/2$. The straight line through the focus and perpendicular to the directrix is the **axis** of the parabola. The point where the parabola crosses the axis is the **vertex.** When the curve is placed in its standard position, the axis is the X-axis and the vertex is the coordinate origin.

The **latus rectum** of the parabola has length $2p$. Its center is at infinity, hence it is a non-central conic.

PARABOLA, CUBICAL. A plane curve represented by the equation $y = kx^3$. There is a **point of inflection** at the origin and the X-axis is tangent to the curve at that point.

PARABOLA, SEMI-CUBICAL. A plane curve represented by the equation $y^2 = kx^3$. There is a **cusp** of the first kind at the origin, where the X-axis is a double tangent.

PARABOLIC CABLE. A flexible cable, generally used as a supporting member for a distributed horizontal load. The load is applied by means of vertical cables, equally spaced horizontally along the length of the cable.

It can be shown by analysis that the cable will assume a parabolic shape under such conditions. The suspension bridge is a common example of the parabolic cable.

PARABOLIC COORDINATES. In a limiting case of confocal **paraboloidal coordinates,** only two surfaces result. There are two families of parabolas with common foci at the origin of a rectangular coordinate system, one extending toward the positive and the other toward the negative Z-direction. Rotate the families about this axis to obtain paraboloids of revolution (ξ, η = const.) and add planes from the Z-axis (ϕ = const.). The position of a point is then given by

$$x = \xi\eta \cos \phi$$
$$y = \xi\eta \sin \phi$$
$$z = \tfrac{1}{2}(\eta^2 - \xi^2).$$

PARABOLIC CYCLINDRICAL COORDINATES. A curvilinear system similar to **parabolic coordinates** with coordinate surfaces consisting of two families which are parabolic cylindrical (ξ, η = const.) and a family of planes (z = const.). A point in this system is given by

$$x = \xi\eta$$
$$y = \tfrac{1}{2}(\eta^2 - \xi^2)$$
$$z = z.$$

PARABOLIC MICROPHONE. See **microphone, parabolic.**

PARABOLIC MIRROR, OFF-AXIS. See **off-axis parabolic mirror.**

PARABOLIC PARTIAL DIFFERENTIAL EQUATION. A special case of the general **partial differential equation** where $B^2(x,y) = A(x,y)C(x,y)$ for all x,y. There is only one set of **characteristic curves** given by $Ady = Bdx$, having the solution λ = constant. The normal form is then

$$\frac{\partial^2\psi}{\partial x^2} = K(x,\lambda)\frac{\partial\psi}{\partial\lambda} + L(x,\lambda)\frac{\partial\psi}{\partial x} + M(x,\lambda)\psi.$$

The diffusion equation, $\dfrac{\partial^2\psi}{\partial x^2} = a^2\dfrac{\partial\psi}{\partial t}$, where t is the time, is an example of this type. Dirichlet conditions on a boundary open at the end towards increasing t assure a unique solution.

PARABOLOID. **A non-central quadric surface** described by the equations

$$\frac{x^2}{a^2} \pm \frac{y^2}{b^2} = \frac{z}{c}.$$

With the upper sign, the surface is an **elliptic paraboloid.** Sections parallel to the XZ- and YZ-planes are parabolas; sections parallel to the XY-plane at $z = k$ are ellipses if k/c is positive but the locus is imaginary if k/c is negative. When $a = b$, the elliptic sections become circles and the quadric is a **surface of revolution** which could be obtained by rotating a parabola about the Z-axis.

A **hyperbolic paraboloid** results when a minus sign is taken in the equation for the surface. Sections parallel to the XZ- and YZ-planes are parabolas; sections parallel to the XY-plane are hyperbolas. When placed in its standard position, as shown by the equation, the origin of the coordinate system is a **saddle point** for the hyperbolic paraboloid. No surface of revolution is obtained in this case.

PARABOLOID(S), CONFOCAL. If one member of a confocal **quadric system** becomes a **paraboloid,** all three of the surfaces are paraboloids. The equation for this case may be taken as

$$\frac{x^2}{A - q} + \frac{y^2}{B - q} = \frac{2z}{C} - \frac{q}{C^2}$$

where $A > B$. When $q > A$ or $q < B$, the surfaces are **elliptic paraboloids** with **vertex** on the negative and positive Z-axis, respectively; when $A > q > B$, the surfaces are **hyperbolic paraboloids.**

PARABOLOIDAL COORDINATES. A **curvilinear coordinate system** of confocal **paraboloids.** If λ, μ, ν are the real roots of a cubic equation in a parameter describing such surfaces, they are **elliptic paraboloids** (λ, μ = const.); $-\infty < \lambda < b^2$; $a^2 < \nu < \infty$ and **hyperbolic paraboloids** (μ = const.), $b^2 < \mu < a^2$ where $a > b > c$ are also constants.

As in the case of ellipsoidal coordinates a convention is needed for the sign of the coordinates. They are related to rectangular coordinates by the equations

$$x^2 = \frac{(a^2 - \lambda)(a^2 - \mu)(a^2 - \nu)}{(b^2 - a^2)}$$
$$y^2 = \frac{(b^2 - \lambda)(b^2 - \mu)(b^2 - \nu)}{(a^2 - b^2)}$$
$$z = \tfrac{1}{2}(a^2 + b^2 - \lambda - \mu - \nu).$$

PARACHOR. A constant relationship, for a given substance, between **surface tension** and **density.** This relationship is of the form

$$[P] = \frac{M\sqrt[4]{\gamma}}{\rho_l - \rho_g}$$

in which $[P]$ is the parachor; M is the molecular weight; γ is the surface tension of the substance, in liquid form, at a given temperature; and ρ_l and ρ_g are the densities of the liquid and vapor at that same temperature.

From the formula above, it follows that the parachor of a substance is proportional to its molecular volume, an additive property. The parachor has been used in deciding the structure of molecules and polymers. It must be used with caution, however, and a number of anomalies are known.

PARA-CURVE CONE. A **curvilinear cone.**

PARALLAX. As an observer moves about, the relative positions of distant objects seem to change. This apparent change of position of distant objects, due to the actual change of position of the observer, is technically known as parallax; and the amount of apparent shift is known as the parallactic shift. The amount of parallactic shift is inversely proportional to the distance of the object.

In taking readings of instruments employing scales and pointers, care must be taken that the eye of the observer and the pointer are both in a line perpendicular to the plane of the scale. To facilitate this, many instruments have a mirror in the plane of the scale so that the observer may eliminate parallax errors by bringing the reflected image of his eye coincident with the pointer and its reflected image.

In focusing optical instruments which include **cross-hair lines** in the focal plane, the method of parallax is probably the best means of adjustment. The **ocular** is first focused until a clear image of the cross-hairs is observed, then the **objective lens** is adjusted until the image of the object being observed shows no parallax when the eye is moved back and forth across the **exit pupil.** This insures that the real image and the cross-hairs are in the same plane.

In astronomy, the parallax of a star is a measure of the amount by which the position of the star varies with respect to very distant stars as the earth moves through half of its orbit, correction for the effects of aberration having been made. The unit is the parsec, which is the distance of a star at which the earth's orbit subtends an angle of one **second** of arc.

PARALLEL ARITHMETIC UNIT. A **computer** unit in which separate equipment is provided to operate (usually simultaneously) on the digits in each column.

PARALLEL AXES, THEOREM OF. The moment of inertia of a rigid body about any axis is equal to the moment of inertia about a parallel axis through the center of mass plus the product of the mass of the body and the square of the perpendicular distance between the two axes.

PARALLEL CONNECTION. **Network elements** are said to be connected in parallel if a common voltage appears across them.

PARALLEL CUT. A Y-cut. (See **crystal, Y-cut.**)

PARALLEL DISPLACEMENT. See **affinely connected space.**

PARALLEL ELEMENTS. (1) Two-terminal **elements** are connected in parallel when they are connected between the same pair of **nodes.** (2) Two-terminal elements are connected in parallel when any **cut-set** including one must include the others.

PARALLEL FEED. See **shunt feed.**

PARALLEL-PLATE COUNTER CHAMBER. See **counter chamber, parallel-plate.**

PARALLEL RESONANCE. See **resonance, parallel.**

PARALLEL-ROD OSCILLATOR. See **oscillator, parallel-rod.**

PARALLEL TRANSMISSION. The system of **information** transmission in which the characters of a word are transmitted (usually simultaneously) over separate lines, as contrasted to **serial transmission.**

PARALLEL TWO-TERMINAL PAIR NETWORKS. **Two-terminal pair networks** are connected in parallel at the input or at the output terminals when their respective input or output terminals are in parallel.

PARALLELEPIPED. A **polyhedron** with parallelograms as faces. Thus a prism with

parallelograms as bases. Its volume is conveniently written as the scalar triple product [**A B C**], where **A**, **B**, **C** are three vectors describing the edges of the parallelepiped. Sometimes called a parallelepipedon.

PARALLELISM, DISTANT. See **distant parallelism.**

PARAMAGNETIC. Offering less reluctance to the passage of magnetic flux than does air, and hence capable of being attracted by a magnet. Paramagnetic substances have, in other words, **magnetic permeabilities** greater than 1.

PARAMAGNETIC ELEMENT. An element having a **relative permeability** slightly greater than unity, usually between 1.000 and 1 001. Paramagnetic is sometimes used to include **ferromagnetic.** Ferromagnetic materials (which may be called just "magnetic" materials) usually have permeabilities considerably in excess of unity and exhibit **hysteresis** effects.

PARAMAGNETIC RESONANCE IN LOW TEMPERATURE TECHNOLOGY. The use of centimeter wave techniques for investigating the **ground-state energy-levels** of **paramagnetic** atoms in a magnetic field.

PARAMAGNETIC SUSCEPTIBILITY, LANGEVIN THEORY. The average magnetic moment of an assembly of magnetic dipoles in the magnetic field is calculated from the **Langevin function,** that is, as if each were a magnet capable of any orientation in the field but subject to averaging over a Boltzmann distribution. The result is

$$\chi = N\mu^2/3kT$$

where μ is the moment of each atom, N is the number of atoms per unit volume, and k is the Boltzmann constant. The relation does not hold except at very low temperatures.

PARAMAGNETIC SUSCEPTIBILITY OF CONDUCTION ELECTRONS. It was shown by Pauli that the **free electrons** in a metal should show a paramagnetic susceptibility of amount (per unit volume)

$$\chi_S = 3N\mu_B{}^2/2kT_F$$

where μ_B is the **Bohr magneton,** T_F the **Fermi temperature,** N the number of electrons per unit volume and k **Boltzmann's constant.** This is the contribution to the total susceptibility due to the *spins* of the electrons; from it must be subtracted the **diamagnetic susceptibility.** According to the **band theory of solids,** χ_S should be changed from the free electron value in proportion to the **effective mass** of the electrons.

PARAMAGNETISM, QUANTUM THEORY OF. Certain atoms, ions and molecules contain electrons with unpaired **spins.** Such electrons may also be in states whose orbital angular momenta are not compensated. In a magnetic field H the energy levels corresponding to the two directions of spin will be split by the amount

$$\Delta E = g\mu_B H$$

where μ_B is the Bohr magneton and g is the **Landé factor** for the particular state concerned. If there are, as there may well be, J levels, all equally spaced, the magnetization is then given by

$$M = NgJ\mu_B B_J(x) \rightarrow NJ(J+1)g^2\mu_B{}^2H/3kT$$

where $x = gJ\mu_B H/kT$, and B_J is the **Brillouin function,** whence the susceptibility can be calculated. The theory for the rare earth ions, and other complicated atoms is very complex, and requires a detailed consideration of the **spin-orbit coupling, crystal field,** and all the apparatus of the theory of **spectral terms.**

PARAMETER. An arbitrary constant, as distinguished from a fixed or absolute constant. Any desired numerical value may be given to a parameter.

PARAMORPH. One of two or more forms of a substance which have the same chemical composition but differ in certain properties.

PARAPHASE AMPLIFIER. See **amplifier, paraphase.**

PARAPOSITRONIUM. The state of **positronium** in which the spins of electron and positron are antiparallel. The 1s state annihilates into two gamma-rays with a mean life of 1.25×10^{-10} sec. If one of these gamma rays is polarized in a particular plane, the other is polarized in a perpendicular plane.

PARASITIC CAPTURE. Any absorption of a **neutron** which does not result in either a **fission** or the production of a desired element.

PARASITIC ELEMENT. A radiating element, not coupled directly to the feed line of the **antenna,** which materially affects the **radiation pattern** of the antenna.

PARASITIC OSCILLATIONS. See **oscillations, parasitic.**

PARASITIC SUPPRESSOR. A device placed in a circuit to prevent parasitic oscillations (see **oscillations, parasitic**). One commonly-used device is simply a resistance of relatively-low magnitude inserted directly in series with a tube-electrode at the socket.

PARA-STATE. (1) In diatomic molecules, such as hydrogen molecules, the para-state exists when the spin vectors of the two atomic nuclei are in opposite (i.e., antiparallel) directions, forming a singlet state, $S = 0$, whereas the ortho-state is the one in which the nuclei are spinning in the same direction. (2) In **helium,** the para-state is a state characterized by a particular mode of coupling of the electron spins (see **parhelium**).

PARAXIAL RAY. A ray which makes a very small angle only with the optical axis of an optical system, and lies close to the axis throughout its length

PARAXIAL SINGLE-SURFACE EQUATION. For a spherical optical surface separating two media

$$\frac{n}{s} + \frac{n'}{s'} = \frac{n' - n}{r}.$$

Here n and n' are the indices of refraction, s and s' the object and image distance from the vertex of the surface, and r is the **radius of curvature** of the surface. In terms of the **focal length** of the surface, the above equation becomes

$$\frac{n}{s} + \frac{n'}{s} = \frac{n}{f} = \frac{n'}{f'}.$$

If distances of object and image are measured from their focal points, the equation takes the Newtonian form $xx' = ff'$.

PARENT. A **radionuclide** that yields a specified nuclide upon disintegration, either directly or as a later member of a **radioactive series.**

PARENT PEAK OR PARENT MASS PEAK. That component of a **mass spectrum** which results from the undissociated molecule.

PARFOCAL. With the lower **focal points** all in the same plane; said of sets of **eyepieces** so mounted that they may be interchanged without varying the focus of the instrument, as a telescope, with which they are used.

PARHELION. One of the bright spectrally colored spots, commonly called "sun dogs," which appear about 22° above and below the sun due to refraction of sunlight by minute ice-crystals in the air.

PARHELIUM. One group or system of terms in the spectrum of helium that is due to atoms in which the **spin** of the two electrons are opposing each other. Another group of spectral terms, the **orthohelium** terms, is given by those helium atoms whose two electrons have parallel spins.

PARITY. A symmetry property of a wave function; the parity is 1 (or even) if the wave function is unchanged by an inversion (reflection in the origin) of the coordinate system, and -1 (or odd) if the wave function is changed only in sign. All nondegenerate stationary states have a definite parity.

PARKER-WASHBURN BOUNDARY. A **grain boundary** chosen so that it consists of a single array of **dislocations,** and observed through a microscope by oblique illumination on a cleavage surface The motion of this boundary under stress is equivalent to the motion of each single dislocation.

PARSEC. A unit used in expressing astronomical distances. To an object at a distance of one parsec, the mean distance from the earth to the sun (one astronomical unit) subtends an angle of one second. In other words, the heliocentric parallax is the reciprocal of the distance in parsecs One parsec is about 19.2×10^{12} miles.

PARSEVAL THEOREM. See **Bessel inequality.**

PARTIAL. (1) A physical component of a complex tone (see **tone, complex**). (2) A component of a sound sensation which may be distinguished as a simple tone (see **tone, simple**) that cannot be further analyzed by the ear and which contributes to the character of the complex sound. The frequency of a partial may be either higher or lower than the basic frequency and may or may not be

an integral multiple or submultiple of the basic frequency (see **frequency, basic**). If the frequency is not a multiple or submultiple, the partial is inharmonic.

PARTIAL CARRY. In computer terminology, a system of executing the **carry** process, in which the carries that arise as a result of a carry are not allowed to propagate.

PARTIAL DIFFERENTIAL EQUATION. **Partial derivatives** of the unknown function are involved. The general **linear second-order partial differential equation** in two variables is

$$A(x,y)\frac{\partial^2 f}{\partial x^2} + B(x,y)\frac{\partial^2 f}{\partial x \partial y} + C(x,y)\frac{\partial^2 f}{\partial y^2}$$

$$= D(x,y)\frac{\partial f}{\partial x} + E(x,y)\frac{\partial f}{\partial y}$$

$$+ G(x,y)f + H(x,y)$$

The two families of curves are given by

$$A\,dy = [B \pm (B^2 - AC)]^{\frac{1}{2}}\,dx,$$

having solutions λ, μ = constant, are the families of **characteristic curves.** When the differential equation is rewritten with λ, μ as independent variables, the equation is in **normal form.** The three cases arising are **elliptic, hyperbolic, parabolic** partial differential equations. The **boundary conditions** appropriate to the various forms are different but they are always needed to fix the functional form of the solution. Problems dealing with the physics of fields usually lead to partial differential equations. (See **equations of mathematical physics.**)

PARTIAL MOLAR QUANTITY. If X is any extensive property of a system of components with n_1 moles of the first component, n_2 of the second, etc., then the partial molar quantities are defined by

$$x_1 = \frac{\partial X}{\partial n_1}, \quad x_2 = \frac{\partial X}{\partial n_2}, \quad \cdots \text{ etc.}$$

$x_1, x_2 \cdots$ are intensive properties of the system.

It can be further shown that the total property of the whole system is given by

$$X = n_1 x_1 + n_2 x_2 + \cdots.$$

PARTIAL NODES. See **nodes, partial.**

PARTIAL PRESSURE. The pressure exerted by each component in a mixture of gases. (See **law of Dalton.**)

PARTIAL WAVE. The component of the **wave function** in a **scattering** process corresponding to a given angular momentum.

PARTICLE, ELEMENTARY. See **elementary particle.**

PARTICLE, MATERIAL. A necessary concept which is introduced when developing the fundamental principles of mechanics. A material particle is characterized by the properties of mass and an observable position in public space and time. It does not possess the property of geometrical extension. From the standpoint of mechanics, **matter** is considered to be made up of an aggregate of particles.

PARTICLE MECHANICS. See **Newton laws of motion; rectilinear motion of a particle; centrifugal force; centripetal force; uniform motion in a circle; mechanics; kinematics;** and **Coriolis effects.**

PARTICLE VELOCITY. See **velocity, particle.**

PARTITION FUNCTION. An expression giving the distribution of molecules in different energy states in a system

$$Z = \Sigma q_r e^{-\epsilon_r/kT}$$

where Z is the partition function, q_r the statistical weight of the rth state of energy ϵ_r, k is the Boltzmann constant, T, the absolute temperature, and the summation is taken over all the energy states of the system. The energy levels ϵ_r may be those attributed to rotation, translation, vibration or electronic energies, etc. In the case where these can be treated as independent in the given system, the complete partition function of the system may be written

$$Z = Z_{rot} \times Z_{trans} \times Z_{vib} \times Z_{elect} \times \cdots$$

where Z_{rot}, Z_{trans}, Z_{vib}, Z_{elect}, are the rotational, translational, vibrational, and electronic partition functions. The partition function is related to the Gibbs free energy and the Helmholtz free energy. (See **free energy (1)** and **free energy (2)**.)

PARTITION NOISE. See **noise, partition.**

PASCAL LAW (LAW OF THE TRANSMISSIBILITY OF PRESSURE). A result which may be obtained by considering the hydrostatic equilibrium of an incompressible fluid in a gravitational field. The law states that the pressure difference between two points in the fluid depends only on the liquid density and the difference of level.

PASCAL RULES. The **diamagnetic susceptibility** of a complex molecule may be estimated from the sum of the atomic susceptibilities of the constituents, together with a correction factor which depends on the nature of the **bonds** between the atoms.

PASCHEN-BACK EFFECT. With increasing magnetic field strength, the magnetic splitting in spectra increases and finally exceeds the multiplet splitting. Under these conditions, as observed by Paschen and Back, the anomalous Zeeman effect (see **Zeeman effect, anomalous**) changes over to the normal, due to the fact that the LS-coupling is broken, and each of the vectors S and L precesses about the direction of the magnetic field. As a result, each of the vectors is quantized separately, the L-vector giving rise to levels of quantum number $M_L = L, L - 1, \cdots, -L$, and the S-vector to levels of quantum number $M_S = S, S - 1, \cdots, -S$.

PASCHEN BOLOMETER. A very small **thermopile** with a triple junction of bismuth-cadmium, silver, and cadmium-antimony, so suspended that a current causes rotation in a magnetic field.

PASCHEN, LAW OF. The **sparking potential** between electrodes in a gas depends on the length of the spark gap and the pressure of the gas in such a way that it is directly proportional to the mass of gas between the two electrodes, i e., the sparking potential is a function of the pressure times the density of the gas.

PASCHEN MOUNTING. A method of mounting a concave diffraction **grating** in which the **slit,** grating and a curved track representing part of the **Rowland circle** are fixed in position. The plate-holder may be placed anywhere on the track, and the spectrum will be in focus.

PASCHEN SERIES. A series of lines in the **infrared** region of the emission spectrum of atomic hydrogen. The wave numbers of the lines in this series are given by the relationship:

$$\bar{\nu} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

where $\bar{\nu}$ is the wave number in reciprocal centimeters, R_H is the **Rydberg constant** for hydrogen (109,677.591 cm^{-1}), n_1 is 3, and n_2 has various integral values greater than 3.

PASS BAND (OF A FILTER). That band of frequencies which are passed with little or no attenuation.

PASSIVE TRANSDUCER. See **transducer, passive.**

PASSIVITY. Iron, cobalt and nickel anodes exhibit the phenomenon of passivity. Under electrolysis, the current and dissolution of the anode increase with applied emf up to a certain point; beyond this (higher emf) the current drops abruptly and the anode practically ceases to dissolve. It is then said to be in the passive state.

PASSIVITY, CHEMICAL. Passivity can be induced without the action of electric current If iron is dipped into concentrated nitric acid, it soon ceases to dissolve, and has become passive The iron will no longer displace silver from solution, for example Stainless steel is an example, in which exposure to air renders the alloy passive.

PASSIVITY, MECHANICAL. The incomplete protection of an anode against dissolution, by a visible (i.e., thick) film of an insoluble compound, as in the sulfation of lead-acid **storage batteries.**

PASSIVITY, THEORIES OF. Passivity appears to be due to a thin layer of oxide on the passive metal. A number of theories have been proposed to explain the formation of this film and the manner in which it protects the metal.

PAST OF AN EVENT, ABSOLUTE. See **absolute past of an event.**

PATCHCORD. A cord containing plugs on either end for making interconnections on a **jackfield.**

PATCH PANEL. A **jackfield.**

PATTERSON-HARKER METHOD. A technique of **x-ray analysis of crystal struc-**

ture, based upon the fact that the square of the absolute value of **structure factor** $F(hkl)$ is a measure of the reflecting power of the corresponding plane, and can be transformed to give a vectorial representation of the interatomic distances in the crystal.

PATTERSON MAP. In the **Patterson-Harker method** of determining **crystal structure,** a map can be constructed (or, at least, a projection of a three dimensional diagram), in which the distances between the origin and any peak represents the vector between two atoms in the crystal. The interpretation of this diagram is not always easy, unless, as in the **heavy atom method,** some of the peaks can be readily identified.

PAULI EXCLUSION PRINCIPLE. The statement that any **wave function** involving several identical particles must be antisymmetric (must change sign) when the coordinates, including the spin coordinates, of any identical pair are interchanged. If the particles in a system can be considered as occupying definite **quantum states,** it follows from the principle that no more than one particle of a given kind can occupy a particular state; hence the name, exclusion principle. The principle applies to **fermions,** but not to **bosons.** Since electrons, protons, and neutrons are **fermions,** the Pauli exclusion principle must be used in the assignment of particles to quantum states in theories of atomic and nuclear structure. (See **shell structure of nucleus;** and see **forbidden transition.**)

PAULI *g*-PERMANENCE RULE. An extension of the **Pauli *g*-sum rule** which states the sum of the g factors for a given M, of a given electron configuration, is constant.

PAULI *g*-SUM RULE. Since in magnetic fields, as intensity increases, the LS-coupling (see **coupling, *LS***) is broken, and the L and S vectors must be quantized separately, the L-vector giving rise to levels of quantum number $M_L = L, L-1, \cdots -L$, and the S-vector to levels of quantum number $M_s = S, S-1, \cdots -S$. Since the change in energy is given to a first approximation by:

$$\Delta E = h\sigma M_L + h\sigma M_S$$

it follows that the sum of the g values for a given value of M remains constant for all field strengths, g being given (for very strong fields) by the relation,

$$g = \frac{M_L + 2M_S}{M_L + M_S}.$$

PAULI SPIN OPERATORS. The anticommuting operators $\sigma_x, \sigma_y, \sigma_z$ satisfying $\sigma_x\sigma_y = i\sigma_z$ and equations obtained from this by cyclic change. They may be represented by the matrices

$$\sigma_x = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}; \quad \sigma_y = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix};$$

$$\sigma_z = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}.$$

First used to represent the spin of the electron in quantum theory, they are closely connected to the Hamilton **quaternions;** and to the **Cayley-Klein parameters,** used in classical physics.

PAULI SPIN SUSCEPTIBILITY. See **paramagnetic susceptibility of conduction electrons.**

PAULI TERM. Extra term added to the **Lagrangian** describing the interaction between a fermion and an electromagnetic field, to take account, in a phenomenological way, of the anomalous magnetic moment of the particle (especially for a proton or neutron).

PAULI-WEISSKOPF EQUATION. The second quantized form of the **Klein-Gordon equation.**

PAULING RULE. A general rule determining how the **coordination polyhedra** pack together in complex crystals. Divide the valence of the positive ion by the number of surrounding negative ions. For each negative ion the sum of such contributions from neighboring positive ions should equal its valence. The rule merely expresses the requirement of local electrical neutrality of the structure.

PATH LENGTH. See **range.**

PEAK CATHODE CURRENT (STEADY-STATE). See **cathode current, peak (steady-state).**

PEAK ELECTRODE CURRENT. See **electrode current, peak.**

PEAK FORWARD ANODE VOLTAGE. See **anode voltage, peak forward.**

PEAK INVERSE ANODE VOLTAGE. See **anode voltage, peak inverse.**

PEAK POWER OUTPUT. See **power output, peak.**

PEAK PULSE AMPLITUDE. See **pulse amplitude, peak.**

PEAK PULSE POWER. The power at the maximum of a **pulse** of power, excluding **spikes.**

PEAK PULSE POWER, CARRIER-FREQUENCY. The power averaged over that **carrier-frequency** cycle which occurs at the maximum of the **pulse** of power (usually one-half the maximum instantaneous power).

PEAK SOUND PRESSURE. See **sound pressure, peak.**

PEAK SPEECH POWER. See **speech power, peak.**

PEAK-TO-PEAK AMPLITUDE. See **amplitude, peak-to-peak.**

PEAKER. See **differentiator.**

PEAKING CIRCUIT. A circuit used to extend the **frequency response** of a **video amplifier.** In a shunt peaking circuit, the impedance of the load circuit of an amplifier stage is raised when a small inductance, included in series with the plate-load resistor, is caused to resonate with the circuit capacitance. In series peaking, a small inductance is included in series with the grid of the next stage. At the higher frequencies, this inductance resonates with the input capacitance of this grid, thus improving the frequency response. Both series and shunt peaking may be included in the same amplifier stage

PEAKING TRANSFORMER. A transformer which is supplied, through a large series impedance, with a voltage of many times the magnitude necessary to produce normal flux densities in the **core.** Twice each cycle, therefore, the flux travels rapidly from one saturation region to the other, resulting in a sharp pulse of induced voltage in a secondary winding. The secondary winding is sometimes made of high-permeability material with a smaller cross-sectional area, to increase the saturation effects resulting in a sharper pulse. Used to provide firing pulses for **ignitrons** and **thyratrons,** it is sometimes also called an impulse transformer.

PEDERSEN POTENTIOMETER. See **potentiometer, Pedersen.**

PEDESTAL. In television, the level of the **video signal** at which **blanking** of the beam occurs.

PEDESTAL LEVEL. See **blanking level.**

PEIERLS-NABARRO FORCE. The force necessary to move a **dislocation** along its **slip plane,** believed to be very much less than the observed **shear strength** of the softest crystals.

PELLIN-BROCA PRISM. See **prism, Pellin-Broca.**

PELTIER COEFFICIENT. The coefficient π_{AB} appearing in the first Thomson relation

$$\pi_{AB} = T\,dE_{AB}/dT$$

for the emf E_{AB}, generated at a junction between metals A and B at temperature T. π_{AB} is equivalent to the amount of heat generated per second when unit current flows from A to B.

PELTIER EFFECT. The **thermoelectric** effect associated with the temperature difference between junctions of dissimilar metals. In **superconductors** the Peltier effect vanishes

PENCIL (OF LIGHT). A homocentric bundle of rays, corresponding to a train of concentric waves.

PENCIL-BEAM ANTENNA. See **antenna, pencil-beam.**

PENDANT DROP METHOD. See **surface tension, methods of measurement.**

PENDULUM. We shall here consider only gravity pendulums, leaving **torsion pendulums** and **magnetic pendulums** to be discussed separately. Let a rigid body of mass M swing on an axis which is located at distance r above its center of mass, and with respect to which axis the **moment of inertia** of the body is I. This motion is mathematically not simple, but if the amplitude of swing is small, certain terms in the differential equation of

motion may be disregarded and the remaining equation readily solved. The solution gives as the period of the complete oscillation

$$T = 2\pi \sqrt{\frac{I}{Mgr}},$$

in which g is the acceleration of a freely falling body. Huygens found experimentally, what may be proved theoretically, that for any given period of oscillation greater than a certain minimum there are two different distances r for which I/r, and hence T, has the same value. If these two distances are laid off on opposite sides of the center of mass, the two points resulting are "conjugate points" (center of suspension and center of oscillation). Denoting the whole distance between these points by l, the period of swing when the pendulum is suspended at either of them is

$$T = 2\pi \sqrt{\frac{l}{g}}.$$

This is the same as the period for an "ideal simple pendulum," i.e., a single particle of mass m suspended by a weightless thread of length l, for which $r = l$, and $I = ml^2$. Kater utilized this principle in his well-known reversible pendulum (see **pendulum, Kater**) It was Huygens who first adapted the pendulum to regulate a mechanism for keeping time and thereby gave us the common clock.

PENDULUM, KATER. Kater devised a number of rigid **pendulums** for comparing the accelerations of gravity at different places on the earth. Any pendulum of fixed length, carried from place to place, will swing in periods inversely proportional to the square root of the value of this acceleration, g, at the respective stations. Therefore if the pendulum has been timed at a station at which the value of g is accurately known, its period at any field station gives at once the value of g at that station.

Kater's best known pendulum is reversible, being provided with two knife edges, facing each other, and carefully adjusted to be at conjugate points with respect to each other. It follows that when such a pendulum is accurately timed, and the distance between the two knife edges accurately measured, the value of g can be calculated by using the formula for the period T of an ideal simple pendulum:

$$T = 2\pi \sqrt{\frac{l}{g}}, \quad \text{or} \quad g = \frac{4\pi^2 l}{T^2}.$$

When this is applied to the Kater's pendulum, l is taken as the distance between the knife edges. Such a pendulum can thus be used for absolute gravity measurements. (See **pendulum, reversible.**)

PENDULUM, PHYSICAL OR COMPOUND. A pendulum which is a rigid body with no restriction on size, shape or composition. When suspended from a fixed axis passing through the body, it undergoes oscillations. (See also **pendulum.**)

PENDULUM, REVERSIBLE. A pendulum which is used for accurate determinations of the acceleration of gravity. By measuring the period corresponding to two different suspension lengths, there is no need for a measurement of the moment of inertia. The acceleration of gravity is given by

$$g = \frac{4\pi^2[l_A{}^2 - l_B{}^2]}{l_A P_A{}^2 - l_B P_B{}^2}$$

where l_A, l_B are two different lengths of suspension to center of mass; P_A, P_B are periods corresponding to the above lengths.

PENDULUM, SIMPLE. A mechanical **oscillator** which consists of a weight suspended from a fixed point by an inextensible member of negligible mass. The weight and suspension are free to perform circular motion about the fixed point. For small displacements, the differential equation for horizontal motion of the pendulum is

$$\frac{d^2x}{dt^2} = -\frac{g}{l}x$$

and the resulting motion is simple harmonic with a period of

$$2\pi \sqrt{\frac{l}{g}},$$

where l is the length of suspension, g is the acceleration of gravity.

PENDULUM, TORSION. A mechanical **oscillator** consisting of a cylinder suspended by a wire from a fixed support. The motion

consists of a rotational oscillation of the cylinder about the suspension as an axis in a plane perpendicular to the axis. For small rotational displacements the motion is simple harmonic and has a period

$$2\pi\sqrt{\frac{I}{L_\theta}},$$

where I is the moment of inertia of the cylinder with respect to wire axis, L_θ is the restoring torque of suspension per unit deflection in radians.

PENETRATING SHOWER. See **shower, penetrating.**

PENETRATION. (1) In general, the process of entering, saturating or piercing. (2) The passage of particles or radiations through solids. (3) The consistency of a material in terms of the depth it is entered by a standard needle under standard conditions.

PENETRATION DEPTH. (1) The distance from the surface of a **superconductor** in a magnetic field at which the intensity of the field has fallen to $1/e$ of its value outside. (2) The distance to which an external magnetic field penetrates into a superconductor from whose bulk it is excluded by the **Meissner effect.** The **London equations** predict a depth $(\Lambda c^2/4\pi)^{1/2} \sim 10^{-5}$ cm in a static field, a result confirmed by observations on small particles. At high frequencies the effect goes over into the eddy-current **skin-depth** appropriate to the density and mobility of the "normal" electrons. (See **superconductivity, two-fluid model.**) (3) In **induction heating** usage, the thickness of a layer extending inward from the surface of a conductor, which has the same resistance to direct current as the conductor as a whole has to alternating current of a given frequency.

PENETRATION FACTOR. The reciprocal of the **amplification factor.** Also called *durchgriff*.

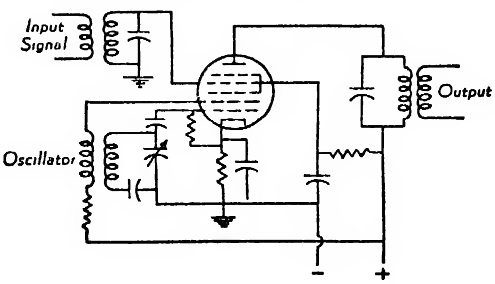
PENETRATION FREQUENCY. See **critical frequency.**

PENETRATION PROBABILITY. The probability of passage of a particle through a potential barrier, defined as a region of finite extent in which the potential energy of the particle exceeds its total energy. An example of barrier penetration is the passage of α-particles through the barrier at the nuclear wall. Penetration of this type is a quantum mechanical phenomenon which cannot be explained in terms of classical physics. In general, the penetration probability increases as the energy of the particle approaches the height of the barrier and as the thickness of the barrier decreases. **Interference** effects, however, play an important role when the thickness of the barrier is a multiple of one-quarter of the wavelength of the **de Broglie wavelength** associated with the particle.

PENETROMETER. (1) A device for measuring **penetrating power** of a beam of x-rays or other penetrating radiation by comparing transmission through various absorbers. (2) An apparatus for determination of the consistency of a material in terms of the depth to which it is entered by a standard needle under standard conditions.

PENNYWEIGHT. A unit of weight in the **troy system** of weights and measures equal to 24 **grains** or about 1.56 **grams.**

PENTAGRID CONVERTER. A **vacuum tube** containing 5 **grids** in addition to the usual **anode** and **cathode.** It is used primarily as a combined **oscillator** and mixer or first **detector** in a superheterodyne **receiver.** In operation the cathode and the first two grids form the cathode, grid and anode of a conventional oscillator circuit. The electrons which would all contribute to the plate current of a conventional oscillator tube largely pass through the openings in the grid-like anode and are then acted upon by the incoming signal which is applied to one of the other grids. Upon finally reaching the real anode of the



tube the electrons have both the effect of the oscillator and the incoming signal, and thus give a combined effect in the output. A typical connection is shown in the figure.

PENTA PRISM. See **prism, penta.**

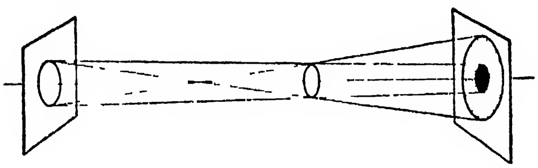
PENTANE CANDLE. A unit of intensity of a light source equal to one-tenth of the standard pentane lamp; approximately equal to the international standard candle.

PENTATRON. The name sometimes applied to a common-cathode double **triode** contained within a single envelope.

PENTODE. A five-electrode, **electron tube** containing an anode, a cathode, a **control electrode,** and two additional electrodes that are ordinarily **grids.**

PENTRIODE AMPLIFIER. See **amplifier, pentriode.**

PENUMBRA. A source of finite size cannot cast a sharp shadow of an intervening opaque object. The central, totally-dark part of the shadow is called the umbra, while the outer,



partially-darkened region is called the penumbra. If the source is larger than the intervening object, then at a sufficient distance, there will be no umbra. These words apply particularly to eclipses of the sun by the moon.

PEPTIZATION. A term applied by Graham to the spontaneous **dispersion** of a solid substance in a liquid on adding a small amount of a third substance, the peptizing agent.

PER CENT ARTICULATION. See **articulation.**

PER CENT CONSONANT ARTICULATION. See **articulation, consonant.**

PER CENT DEAFNESS. See **hearing loss, per cent.**

PER CENT HEARING. See **hearing, per cent.**

PER CENT HEARING LOSS. See **hearing loss, per cent.**

PER CENT INTELLIGIBILITY. See **articulation.**

PER CENT MODULATION. The **modulation factor** expressed as a percentage.

PER CENT RIPPLE. See **ripple, per cent.**

PER CENT SOUND ARTICULATION. See **articulation, sound.**

PER CENT SYLLABLE ARTICULATION. See **articulation, syllable.**

PER CENT VOWEL ARTICULATION. See **articulation, vowel.**

PERCRYSTALLIZATION. The crystallization of a dissolved substance from a solution, during or after **dialysis.**

PERCUSSION. See **kinetics.**

PERFECT RADIATOR. See **complete radiator.**

PERIDYNE RECEPTION. An early radio-receiver which was tuned by a box-enclosed **inductor.** The inductance was changed by changing the position of a metal screen with respect to the inductor.

PERIGON ANGLE. See **angle.**

PERIHELION. The point at which a planet or other body moving about the sun approaches the sun most closely.

PERIHELION OF MERCURY (ROTATION OF). The observed rate of rotation is 572.7 seconds per century, of which 529.2 seconds are due to the perturbating fields of the other planets. The **Schwarzschild solution** of the **Einstein law of gravitation** yields an extra theoretical value of 42.9 seconds. The agreement is a strong argument in favor of general relativity theory. (See **relativity theory, general.**)

PERIKON DETECTOR. See **detector, perikon.**

PERIOD. (1) An interval, especially one established by repeated or regular recurrence, or the entities contained within such an interval. (2) Of a periodic quantity, the smallest value of the increment of the independent variable for which the function repeats itself. (Also called **primitive period.**) (3) A sequence of elements in the **periodic table,** arranged by atomic number and properties.

PERIOD, HALF-LIFE. See **half-life.**

PERIOD, LONG. The third, fourth, or fifth periods of the **periodic table** and the elements they contain. The third period extends from

argon (atomic number 18) to bromine (atomic number 35); the fourth period extends from krypton (atomic number 36) to iodine (atomic number 53); and the fifth period from xenon (atomic number 54) to astatine (atomic number 85).

PERIOD, NATURAL. The period of a free oscillation of a body or system (See **oscillation, free.**)

PERIOD OF DEFORMATION. Time from initial impact until bodies cease to approach. (See **period of restitution; impact.**)

PERIOD OF RESTITUTION. Time from maximum compression until bodies are ultimately separated and moving with final velocities. (See **impact.**)

PERIOD, RARE EARTH. The period (fifth) of the **periodic table** which includes the rare earth elements (the elements from atomic number 57 to atomic number 71, inclusive): lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutecium. The fifth period extends from xenon (atomic number 54) to astatine (atomic number 85).

PERIOD, REACTOR. The time required for the **neutron flux** to change by a factor of e.

PERIOD, SHORT. The first or second periods of the **periodic table,** and the elements they contain. The first period extends from hydrogen (atomic number 1) to fluorine (atomic number 9); and the second period extends from neon (atomic number 10) to chlorine (atomic number 17).

PERIOD, STABLE REACTOR. The reactor period (see **period, reactor**) after a lapse of sufficient time to permit the contributions of **transient terms** to damp out

PERIODIC. See **function, periodic** and **periodic quantity** for the general use of this term.

PERIODIC ANTENNA. See **antenna, resonant.**

PERIODIC CHAIN. An arrangement of the **periodic system** in the form of a simple vertical listing of the elements in order of increasing **atomic numbers,** and divided by horizontal lines.

PERIODIC ELECTROMAGNETIC WAVE. See **wave, periodic electromagnetic.**

PERIODIC FOCUSING FIELDS. A method of electron beam focusing which utilizes a number of short, focusing fields that vary periodically along the electron stream, and constitute a series of thick or thin **electron lenses.**

PERIODIC LAW. The statement that the elements may be arranged in a **periodic table.**

PERIODIC LINE. A resonant line.

PERIODIC PULSE TRAIN. See **pulse train, periodic.**

PERIODIC QUANTITY. An oscillating quantity, the values of which recur for equal increments of the independent variable. If a periodic quantity, y, is a function of x, then y has the property that

$$y = f(x) = f(x + k),$$

where k, a constant, is a period of y. The smallest positive value of k is the primitive period of y, generally called simply the period of y. In general, a periodic function can be expanded into a series of the form

$$y = f(x) = A_0 + A_1 \sin (\omega x + a_1) + A_2 \sin (2\omega x + a_2) \cdots$$

where ω, a positive constant, equals 2π divided by the period k, and the A's and a's are constants which may be positive, negative, or zero. (See also **Fourier series.**)

PERIODIC SYSTEM. An arrangement of the elements in a systematic grouping wherein elements having like properties occur in related positions, as in horizontal or vertical sequence, so that unknown properties of known elements, and even properties of unknown elements, can be deduced from their positions in this arrangement. The arrangement of the elements of the system is based on the **atomic number** of each element.

PERIODIC TABLE. An arrangement of the periodic system in the form of a table, which is the most common arrangement.

PERIODICITY. The recurrence of an event, phenomenon, or characteristic feature at regular intervals of time, distance, or other variable.

PERISPHERE. The volume surrounding an object in which the gravitational, magnetic, or electric fields of the object produce observable effects.

PERITECTIC. A point at which **incongruent melting** takes place.

PERMALLOY. A series of high permeability nickel-iron magnetic alloys. In the United States the number prefix indicates the per cent nickel (i e., 65 permalloy is 65% nickel).

PERMALLOY, MOLYBDENUM. A nickel-molybdenum, high-permeability alloy The two varieties in general use are 4-79 (4% Mo, 79% Ni, balance Fe) and 2-81 (2% Mo, 81% Ni, balance Fe).

PERMANENT GASES. An historic classification that included those gases which are very difficult to liquefy and which were thought to be nonliquefiable The distinction has vanished since all the gases have been liquefied because of the advance in low temperature techniques.

PERMANENT MAGNET LOUDSPEAKER. See **loudspeaker, permanent magnet.**

PERMATRON. A hot-cathode, gas-discharge **diode** in which the start of conduction is controlled by an external magnetic field.

PERMEABILITY (μ). (1) Absolute permeability, B/H, or **magnetic induction** divided by **magnetizing force.** (2) Specific (relative) permeability μ_s B $\mu_i H$ (μ_i permeability of vacuum). These meanings are distinct in the **mksa system,** but not in the usual cgs **emu system,** where μ_v is defined to be unity (3) The capacity of a membrane or other material to allow another substance to penetrate or pass through it; or the quantity of a specified gas or other substance which passes through under specified conditions.

PERMEABILITY, DIFFERENTIAL. The slope of the **magnetization** curve.

PERMEABILITY, DYNAMIC. The **permeability** determined by the slope of a line joining the tips of a dynamic hysteresis loop (see **hysteresis loop, dynamic**) under specified conditions.

PERMEABILITY, IDEAL. The ratio of B (**magnetic induction**) to H (**magnetizing force**) obtained by superposing a large alternating ΔH on the desired H, and slowly reducing ΔH to zero.

PERMEABILITY, INCREMENTAL. The ratio of a small cyclic change in **induction** (B) to the corresponding cyclic change in **magnetizing force** (H); or the slope of the B-H curve when an alternating **magnetizing force** is imposed on a direct magnetizing force

PERMEABILITY, INITIAL (μ_0). The limit approached by the normal permeability as the **magnetizing force,** H, and the **magnetic induction,** B, approach zero

PERMEABILITY, MAXIMUM. The largest value of **normal permeability** (obtained by varying H), or the maximum value of incremental permeability (see **permeability, incremental**); or the maximum slope of the B-H curve

PERMEABILITY, NORMAL. The ratio of **normal induction** to the corresponding **magnetizing force.**

PERMEABILITY, REVERSIBLE (μ_r). The limit of incremental permeability (see **permeability, incremental**) as the incremental change in **magnetizing force** approaches zero

PERMEABILITY, SPECIFIC (μ_s) (RELATIVE PERMEABILITY). The ratio of the absolute permeability (see **permeability, (1)**), of a substance to the permeability of free space

PERMEABILITY TUNING. The variation of the resonance frequency of the tuned circuits of a receiver or transmitter by changing the effective permeability of the inductor's core The most general way in which this is done is by varying the position of a **ferrite** slug with respect to the coil. An alternate method, which is less used because of its deleterious effects on the **Q** of the coil, decreases the coil inductance by inserting a brass, copper or aluminum slug into the center of the coil.

PERMEATE. (1) To pass through a substance, as in the case of a gas or liquid which passes through small channels or pores in a membrane or other medium. (2) **To pass into**

an object or substance as by traveling through minute openings or intermolecular spaces, so that the diffusing substance becomes more or less uniformly distributed throughout the medium into which it travels.

PERMEAMETER. An **electromagnet** arranged for magnetizing a specimen, and allowing measurement of the **flux** through the specimen and the **magnetizing force** at the surface. Various types of permeameter have been designed, aiming at ease of operation, accuracy of results, or use with high-**coercivity** materials.

PERMENDUR. A 50% cobalt, 50% iron alloy with a high **permeability** at a saturation flux density. It is, in fact, higher than that of most other materials.

PERMENORM 5000Z. The first 50% nickel, 50% iron, highly-oriented, magnetic alloy. Similar materials are more frequently known as **Deltamax, Hipernik V, Orthonal** and **Orthonik.**

PERMINVAR. The class of nickel, iron and cobalt magnetic alloys which are characterized by constant **permeability,** and low **hysteresis loss** at low inductions.

PERMISSIBLE DOSE. The amount of radiation which may be received by an individual within a specified period with expectation of no harmful result to himself. For long-continued x- or γ-ray exposure of the whole body it is 0.3 r per week measured in air (For detailed information, see *National Bureau of Standards Handbooks* 41, 42, etc.)

PERMITTIVITY OR DIELECTRIC CONSTANT. The Coulomb law for two charges immersed in a dielectric medium gives the mutual force as

$$F = \frac{q_1 q_2}{\epsilon r^2}.$$

The constant ϵ is the absolute permittivity of the medium, and the ratio $\epsilon/\epsilon_0 = K$ is the relative permittivity or dielectric constant. ϵ_0 is the **electric constant** or the permittivity of free space. (See **dielectric constant.**)

In rationalized systems of units (see Introduction) the Coulomb law is written

$$F = \frac{q_1 q_2}{4\pi\epsilon_r r^2}$$

and the permittivity ϵ_r is less than in unrationalized systems by a factor of 4π.

PERMUTATION(S). Each different arrangement in a definite order which can be made of all or part of a given set of elements. The number of permutations of n things taken r at a time is denoted by many different symbols; the most commonly used are ${}_nP_r$, $P_{n,r}$ and $P(n,r)$ and is given by $n(n-1)(n-2)\cdots(n-r+1)$, (r factors in the expression). The number of permutations of n things taken n at a time is $n(n-1)\cdots 3\cdot 2\cdot 1 = n!$. If, of n things, p are all alike, of one kind, q of another kind, r of another, and so on, the number of permutations of these things taken all together is

$$\frac{n!}{p!q!r!}.$$

PERMUTATION, CYCLIC. A permutation sending t_1 into t_2, t_2 into t_3, etc., and finally t_n into t_1 is called a **cycle** on n letters. It is usually written as $(t_1, t_2 \cdots t_n)$. The degree of a cycle is equal to the number of symbols permuted.

PERMUTATION, EVEN OR ODD. A permutation may always be written as a product of **transpositions,** either even or odd in number. The permutation is then said to be even or odd. (See **group, alternating; group, symmetric.**)

PERPETUAL MOTION. The idea of a mechanism which, once started, would operate indefinitely. It has never been achieved because of the inability to free macroscopic moving bodies completely from friction and hence from dissipation of mechanical energy.

PERPETUAL MOTION, FIRST KIND. A device which produces power without energy uptake. Thus a perpetual motion, once started, would operate indefinitely. Such a device would violate the law of **conservation of energy** and is therefore impossible.

PERPETUAL MOTION, SECOND KIND. A device which converts heat *completely* into other forms of energy. Such a device would violate the second law of **thermodynamics** (see also **entropy**) and is therefore impossible.

PERRIN DETERMINATION OF THE AVOGADRO NUMBER. Perrin determined the **Avogadro constant** by making measurements of the movements and distribution of

colloidal particles in water. This was done (a) by evaluating the variation of distribution with height of particles of the same mass and density, which is defined by

$$\frac{1}{n}\frac{dn}{dz} = -\frac{mg}{RT}\frac{\rho - \rho_l}{\rho}N$$

where n is the number density of the particles, z is vertical displacement, m is the mass of the particles, R is the gas constant, ρ, ρ_l are the densities of the particles and the liquid, N is Avogadro's number, and (b) by observing the mean rate of dispersion of spherical particles from their original positions as a result of Brownian movement. (See **Einstein diffusion equation.**)

PERRIN RULE. A generalization derived from certain results on **electroosmosis,** to the effect that ions of charge opposite to that of the diaphragm have by far the greatest effect upon endosmosis, and that the higher their valence (if it is of opposite sign) the greater the reduction of electroosmotic flow.

PERSISTENCE CHARACTERISTIC (DECAY CHARACTERISTIC) (OF A LUMINESCENT SCREEN). A relation, usually shown by a graph, between emitted **radiant power** and time after excitation.

PERSISTENT SPECTRUM. See **spectrum, persistent.**

PERSONAL EQUATION. In making measurements of any character every observer, no matter how skilled he may be, is bound to make certain errors. These errors are of two kinds: accidental errors which will be small in the case of a good observer and which will be distributed in accordance with the **laws of probability;** and systematic errors or errors which are always in the same direction and of approximately the same magnitude. The value of the systematic error is known as the personal equation of the observer. Personal equation must be determined empirically for each observer under a variety of different observing conditions. For a good observer the personal equation remains remarkably constant over long periods of time and may be applied directly to any observation.

PERSORPTION. A term applied by McBain to **adsorption** in which the adsorbed molecules occupy vacant spaces in the lattice of the adsorbing material. An example of this type of adsorption is that of water by the zeolites.

PERTURBATION THEORY. The study of the effect of small changes on the behavior of a system. In the general treatment of a problem by the method of perturbations, a differential equation which neglects the small change is solved. The resulting solution is then substituted into a more exact differential equation and terms which are of second order or higher in the ratio of the change of the solution to the original solution are neglected. The resulting equation for the change, in terms of the causes of perturbation and the original solution, is often far simpler than the exact equation, including the perturbing effects, would have been

PERVEANCE. The quotient of the space-charge-limited cathode current by the $\frac{3}{2}$-power of the anode voltage in a **diode.** Perveance is the constant G appearing in the Child-Langmuir-Schottky equation.

$$i_k = Ge_b{}^{3/2}.$$

When the term perveance is applied to a triode or multi-grid tube, the anode voltage e_b is replaced by the composite controlling voltage e' of the equivalent diode. For Child-Langmuir equation on which this is based, see **space charge limitation of currents.**

PETZVAL CONDITION. To eliminate the aberration of **curvature of field,** at least two lenses must be used which are so related that they satisfy the Petzval condition; $f_1n_1 + f_2n_2 = 0$, where the subscripts refer to the two lenses, respectively, n is the index of refraction and f is the focal length.

PETZVAL SURFACE. By changing the separation of a doublet lens, a condition free from **astigmatism** may be found, but the field will not then be flat The single, paraboloidal surface over which point images of **point objects** are formed is called the Petzval surface.

PFAFF EXPRESSION. A differential equation

$$dW = \sum_{\lambda=1}^{n} X_\lambda dx_\lambda$$

where the X_λ are functions of the independent variables and dW is a **total differential.** In general the value of W depends upon the path of integration, whereupon the expression is an **inexact differential.** If the value of W is in-

dependent of the path of integration, the expression is an **exact** or **perfect differential.** Equations of these forms occur in thermodynamics.

PFAFF PROBLEM. A non-integrable **total differential equation.** If it contains $2n$ or $(2n - 1)$ variables, it is equivalent to not more than n algebraic equations. Thus, if there are three variables, the general solution is an arbitrarily chosen relation $f(x,y,z) = 0$ and a second relation containing an arbitrary constant $g(x,y,z) = 0$. Pfaff's problem may be interpreted geometrically and is of some importance in advanced theories of mechanics and thermodynamics.

PFUND SERIES. A series of lines in the **infrared** region of the emission **spectrum** of atomic hydrogen. The wave numbers of the lines in this series are given by the relationship.

$$\bar{\nu} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

where $\bar{\nu}$ is the wave number in reciprocal centimeters, R_H is the **Rydberg constant** for hydrogen (109,677.591 cm^{-1}), n_1 is 5, and n_2 has various integral values.

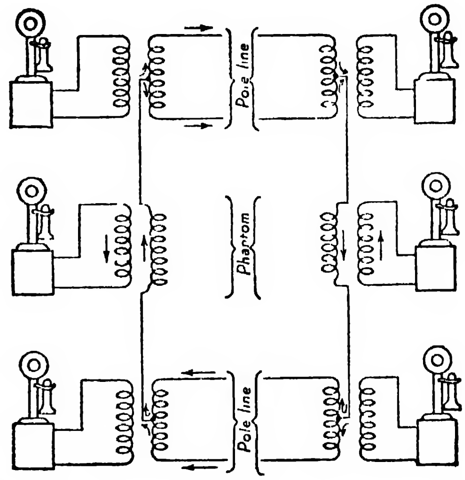
pH. A measure of the hydrogen ion activity (or concentration) in an aqueous **electrolyte.** It is the logarithm (base 10) of the reciprocal of the hydrogen ion activity (or concentration) in grams per liter. pH values below 7 indicate an acid condition; above 7, alkaline.

PHANATRON. A gas-filled, hot-cathode **rectifier tube.**

PHANTASTRON. A certain type of one-tube relaxation oscillator (see **oscillator, relaxation**) employing **Miller feedback** to generate a linear timing waveform

PHANTOM CIRCUIT. One metallic communication circuit and a ground connection can be made to carry two messages simultaneously with the addition of certain equipment. Similarly, two metallic circuits can add a third metallic message-channel. In addition, each of the original circuits may be operated with suitable equipment and ground connections to provide two additional message channels creating a total of three metallic-path and two ground-path independent message channels.

The figure illustrates a circuit "phantomed" on two standard metallic circuits. The in-



Illustrating a circuit "phantomed" on two standard circuits (arrows give current flow when phantom is in use)

stantaneous direction of current is shown by arrows. The repeating coils or transformers are center-tapped so that the current in the phantom divides equally in those coils. •If the current flow in the side lines (called physical circuits) is equal, and moving oppositely so far as the side-line circuit is concerned, their **magnetomotive forces** will cancel and no induced voltages will be present in the side circuits. Thus the side circuit is not affected by the phantom.

PHANTOM LOADING. A scheme for testing and calibrating **wattmeters** (and **watthour meters**) by supplying the voltage and current connections from independent adjustable sources, rather than using actual loads.

PHASE. (1) One of two or more forms, appearances, or forms of behavior exhibited by the same entity, as the phases of the moon, of alternating electric current, of protoplasm, and of bacteria (2) The argument of the harmonic function in the mathematical expression for the disturbance in a harmonic wave, viz., in $u = Ae^{i(\omega t - kx)}$, $(\omega t - kx)$ is the phase. In the harmonic oscillation, $x = Ae^{i(\omega t + B)}$, $\omega t + B$ is the phase, and B is the initial phase or epoch. (3) A homogeneous, physically-distinct part of a system which is separated from other parts of a system by definite bounding surfaces. Thus a gas, a homogeneous liquid, or a homogeneous solid

is a single phase, while, for example, a system of two insoluble or partly-soluble liquids which form separate layers has two phases, and a system of two solids in equilibrium with their solution has three phases.

PHASE ANGLE. A conventional representation of simple harmonic motion is

$$y = A \sin (\omega t + \alpha) = A \sin \left(\frac{2\pi t}{T} + \alpha\right)$$

in which A is the amplitude, $\omega t + \alpha$ or $\frac{2\pi t}{T} + \alpha$ is the phase angle, and α is the epoch angle, t is the time variable, T is the period and ω is the angular velocity.

Two coherent harmonic motions, described by

$$y_1 = A \sin (\omega t + \alpha)$$

and

$$y_2 = A \sin (\omega t + \beta)$$

are said to have a phase difference of $(\beta - \alpha)$.

PHASE ANGLE, ACOUSTIC. The angle whose tangent is the ratio of the acoustic reactance to the acoustic resistance. (See **reactance, acoustic** and **resistance, acoustic.**)

PHASE, CONTINUOUS. The enveloping **phase** (3) in a system which contains one or more disperse phases. It is also called the dispersion medium.

PHASE CONSTANT. Of a **traveling plane wave** at a given frequency, the space rate of decrease of phase of a field component (or of the voltage or current) in the **direction of propagation,** in radians per unit length.

PHASE CONSTANT, IMAGE. The imaginary part of the **transfer constant.**

PHASE - CONTRAST MICROSCOPE. A **compound microscope** has added to it an annular diaphragm, placed at the front focal plane of the substage condenser, and a phase plate, placed at the focal plane of the first group of lenses in the objective. The phase plate consists of a glass plate, on which is deposited an annular layer of transparent material, which increases the optical path by one-quarter wavelength. The **diffraction** pattern of an object point is so augmented by these changes that objects which differ only in **optical path,** but not necessarily in **density,** become visible.

PHASE CONTROL. The control of the output current of **thyratrons, ignitrons,** and similar devices by controlling the time or phase angle of the supply cycle at which the tube fires or conducts. This is achieved by shifting the phase of the voltage which provides the firing impulse to the tube, with respect to the supply voltage.

PHASE CONVERTER. If single-phase voltage is applied to one **phase** of a rotating three-phase induction **motor** it will be found that approximately balanced three-phase voltages may be obtained from the three terminals of the machine. This is because the rotating field induces voltages in the various phase windings which are not much different from the applied voltage. Since the single-phase field is not quite uniform and since the impedance drop in the windings affects the terminal voltage, the output voltages are not quite equal, but nearly enough so that they may be used for much three-phase work This method is used quite widely in a-c railway electrification since the necessity of three conductors makes transmission of three-phase power to the locomotive difficult.

PHASE, CRYSTAL (α-, β-, γ-, ϵ-, η-, **etc.**). See **crystal phases** (α-, β-, γ-, ϵ-, η-, **etc.**)

PHASE DIAGRAM. A graph showing the condition of **equilibrium** between various phases of a substance or of different substances.

PHASE DEVIATION. The peak difference between the instantaneous angle of the **modulated wave** and the angle of the **carrier.**

PHASE DIFFERENCE. See **phase angle.**

PHASE DIFFERENCE VS. PATH DIFFERENCE. The difference in phase between two coherent wave disturbances that have traveled over different **optical paths,** from some point at which they had the same phase, is $2\pi/\lambda$ times the path difference, where λ is the wavelength.

PHASE DISCRIMINATOR. See **discriminator, phase.**

PHASE, DISPERSE. A system of one or more **components,** with definite boundaries, which is dispersed within another medium, called the continuous phase.

PHASE DISTORTION. See **phase-frequency distortion.**

PHASE EFFECT IN BINAURAL LISTENING. See **binaural phase effect.**

PHASE EQUALIZER. A **network** designed to compensate for **phase-frequency distortion** in a system.

PHASE FACTOR, OR CONSTANT. The essential difficulty in the **X-ray analysis** of **crystal structure** is that there is no means of measuring the relative phases of the various reflected beams. Thus, only the absolute magnitudes of the **structure factors** can be found, and in order to carry out a **Fourier synthesis** of the structure, the phase constants have to be estimated or guessed.

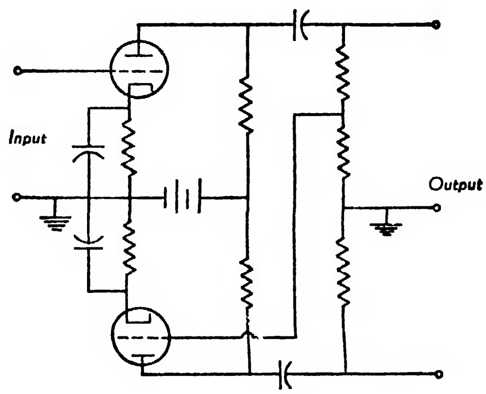
PHASE FOCUSING OR HERRINGER-HÜLSTER EFFECT IN MAGNETRONS. A **bunching** effect in **magnetrons** which causes an electron which is behind the position of maximum tangential force to be subjected to a small, added, radial component of electric force. This, together with the impressed magnetic force B, will give the electron an added tangential velocity and will, therefore, tend to bring it into step. An electron that is ahead of schedule will find a smaller radial component, and will be forced back into step.

PHASE-FREQUENCY DISTORTION. Distortion due to lack of direct proportionality of phase shift to frequency over the frequency range required for transmission. Delay distortion is a special case. This definition includes the case of a linear phase-frequency relation with the zero frequency intercept differing from an integral multiple of π.

PHASE, INITIAL (OR EPOCH). See **phase.**

PHASE INTEGRAL. See **action variable.**

PHASE INVERTER. The push-pull **amplifier** has numerous advantages over single-ended ones but does require a push-pull connection for driving the **grids.** Since the usual amplifier has low-level stages operating single-ended this requires some method of getting two equal voltages 180° out of phase to drive the push-pull grids. One method is to use a **transformer** to couple one single **plate** to the push-pull grids by center-tapping the **secondary.** However, for resistance coupling a phase inverter may be used. Referring to the figure, part of the output voltage of the



upper tube is coupled back into the grid of the lower tube. Since the output of a tube is 180° out of phase with the input, the input to the second tube is 180° from that of the first tube, hence their outputs are likewise displaced. If the tap on the output resistor of the first tube is adjusted correctly just enough voltage is applied to the grid of the second to cause its output to be equal that of the first. These equal and opposite voltages may then be applied to the push-pull grids of the following stage.

PHASE MARGIN. A stability criterion for **feedback** systems equal to 180° minus the total **phase-angle** encountered in the **feedback loop** at the frequency where the **loop gain** is unity.

PHASE MODULATION OR PM. See **modulation, phase** or **PM.**

PHASE OF A PERIODIC QUANTITY. The phase of a **periodic quantity,** for a particular value of the independent variable, is the fractional part of a **period** through which the independent variable has advanced, measured from an arbitrary origin. In the case of a simple sinusoidal quantity, the origin is usually taken as the last previous passage through zero from the negative to positive direction. The origin is generally so chosen that the fraction is less than unity. The phase is expressed in **radians,** rather than in periods, in which use its numerical value is increased by a factor of 2π.

PHASE OF THE WAVE. For an oscillating wave, expressed as $Ae^{j(\omega t - \beta x + \theta)}$, the phase

of the wave is either θ or $(\omega t - \beta x + \theta)$ according to the author's usage.

PHASE-PROPAGATION RATIO. The **propagation ratio** divided by its magnitude.

PHASE RESONANCE. See **resonance, velocity**; and **resonance, frequency of.**

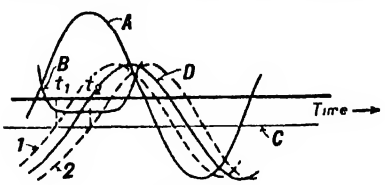
PHASE REVERSAL. A change of phase equal to one-half cycle, such as may be experienced by light waves upon reflection under certain conditions.

PHASE RULE, THE. A mathematical expression which shows the conditions of **equilibrium** in a system as a relationship between the number of **phases,** the number of **components,** and the **degrees of freedom** possible under the given conditions. If C represents the number of components, P, the number of phases, and F, the degrees of freedom, then $C + 2 - P = F$.

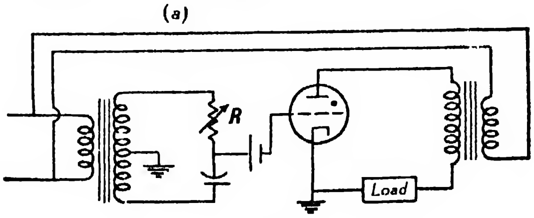
PHASE SECTION, DIFFERENTIAL. See **differential phase-section.**

PHASE-SENSITIVE RECTIFIER. A phase **discriminator.**

PHASE SHIFT CONTROL. This control is commonly applied to **thyratrons** or **ignitrons** operated on a-c and consists of controlling the breakdown point by shifting the phase of the grid voltage with respect to the anode voltage. Fig. a shows the anode voltage (A),



(a)



(b)

the grid characteristic (B), the d-c grid **bias** (C) and the a-c grid voltage (D). These are all plotted against time along the horizontal axis. If at any instant the net grid voltage, i.e., the d-c plus the a-c value, goes above the characteristic (B) the tube breaks down and conducts for the rest of that half-cycle. Thus if the grid wave is shifted to position (1) the tube breaks down at time t_1 while if it is shifted to (2) the tube breaks down at t_2. By making the phase continuously variable the average output of the tube may be varied by varying the part of the cycle over which the tube conducts. A simple circuit for doing this is shown at (b). The voltage applied to the **grid** may be varied over nearly 180° by varying the value of the resistor R. This method of controlling tubes is widely used for motor speed control and for resistance welding control.

PHASE SHIFT FOR SCATTERING. One of several angles having a value between $+\pi$ and $-\pi$, giving the phase relation between a **scattered wave** and an **incident wave** associated with the particle or photon that undergoes scattering.

PHASE-SHIFT MICROPHONE. See **microphone, phase-shift.**

PHASE-SHIFT OSCILLATOR. See **oscillator, phase-shift.**

PHASE-SHIFTER, WAVEGUIDE. See **waveguide phase-shifter.**

PHASE SLOWNESS. Consider a harmonic wave

$$V = A(x,y,z)e^{j[\omega t - \Phi(x,y,z)]}.$$

The phase slowness is the vector

$$\mathbf{S} = \frac{1}{\omega}\nabla\Phi.$$

The reciprocals of the components of **S** are the speeds of propagation of constant phase along the corresponding axes. Since these speeds are *not* the components of a velocity vector, **phase velocity** is not conveniently generalized from one dimension to three.

PHASE SPACE (OR GAMMA SPACE). A Euclidean hyperspace of $2f$ dimensions, having $2f$ rectangular axes, one for each of generalized coordinates q_1, q_2, q_3 $\cdots$ q_f, and one for each of the corresponding momenta, p_1, p_2, p_3 $\cdots$ p_f. By classical mechanics, it is possible to define completely the instantaneous state of any system of n degrees of freedom by means of a phase point in this $2n$ dimensional hyperspace.

PHASE STABILITY, PRINCIPLE OF. In a frequency-modulated **cyclotron,** the changed particle should be accelerated in each cycle at a time just beyond that corresponding to the peak value of the accelerating potential. If the particle arrives at a time slightly different from this, it will receive a greater (or smaller) increment in energy, hence in mass (at relativistic energies). The time it takes to traverse the orbit will then be changed such that on the next cycle it tends to arrive at the proper time. The rotation of the charged particle is thus automatically synchronized with the changing frequency of the accelerating potential.

PHASE VELOCITY. Of a **traveling plane wave** at a single frequency, the velocity of an **equiphase surface** along the **wave normal.** (See also **group velocity.**)

PHASE VERSUS FREQUENCY RESPONSE CHARACTERISTIC. A graph or tabulation of the **phase shifts** occurring in an electrical **transducer** at several frequencies within a band.

PHASITRON. A **frequency-modulator** tube designed to make possible the introduction of comparatively-wide phase excursions at audio rates in a crystal-controlled, radio-frequency carrier voltage.

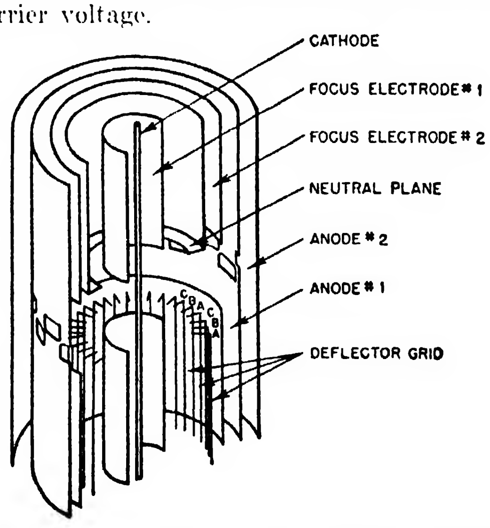


Fig. 1. Cut-away view of the GL-2H21 phasitron (By permission from "The Radio Manual" by Sterling and Monroe. 4th Ed., Copyright 1950, D. Van Nostrand Co., Inc.)

In the cut-away view of the phasitron, anodes 1 and 2 are maintained at a positive d-c potential, and draw electrons from the cathode. By means of the two focus electrodes, these electrons are formed into a tapered, thin-edged disc. This disc, with the cathode as its axis, lies between the neutral plane and the deflector grid structure, and extends to anode 1.

The deflector grid consists of 36 separate grid wires. These wires are lettered A, B, C, A, B, etc. All the A grid wires are connected together as are all the B grid wires and all the C grid wires.

The output of a crystal-controlled **oscillator** is amplified, and fed into a phase-splitting network that converts the single-phase, radio-frequency voltage to a three-phase voltage. This three-phase voltage is connected to grids A, B, and C so that they have equal magnitudes of voltage 120° apart.

The deflection action on the disc of electrons is as follows: Consider the time when the voltages on A grids are a positive maximum. The beam will be deflected downward towards all A grids, but repelled equally from B and C grids which have equal negative potentials at this time. The edge of the beam would become serrated as shown in the second figure. 120° later the beam will be deflected

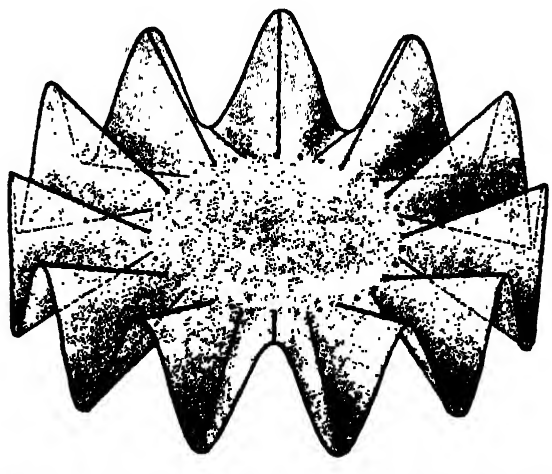


Fig. 2. Perspective view of electron disc (By permission from "The Radio Manual" by Sterling and Monroe, 4th Ed., Copyright 1950, D. Van Nostrand Co., Inc.)

downward towards B, and repelled equally from A and C, so the electron disc will have the same form, but will appear to have revolved the distance between grids.

The third figure shows a plane view of anode 1. The anode has 24 holes, 12 above the plane of the electron disc, and 12 below.

The rotating, serrated edge of the electron disc impinges on this series of holes. At an

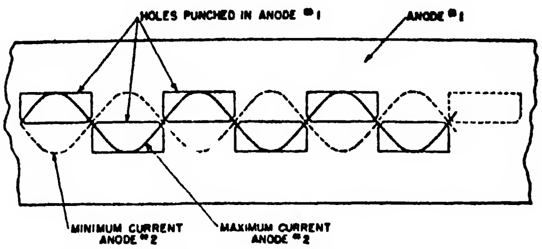


Fig 3 Developed view of anode (By permission from "The Radio Manual" by Sterling and Monroe, 4th Ed, Copyright 1950, D Van Nostrand Co, Inc)

instant when the disc edge is lined up, as shown by the solid line in the third figure, most of the electrons pass on through to anode 2 180° later the edge of the disc has moved to the position shown by the dotted line and few, if any, electrons get through to anode 2 Thus, the current flowing to anode 2 varies sinusoidally at the crystal frequency. Also, it can be seen that any change in the angular velocity of rotation of the disc will result in phase and frequency variation in the output

A current-carrying coil placed around the tube produces a magnetic field perpendicular to the plane of the electron disc This magnetic field thus is capable of producing an angular displacement of the disc, causing phase shift in the output current so indicated above. The flow of modulating currents thus produces a proportional magnetic field which causes a proportional change in angular displacement of the disc, the result being an anode 2 current modulated in phase proportional to the modulating signal.

PHASMAJECTOR. The name sometimes applied to a **monoscope.**

PHI. (1) Electron affinity (net work function) (ϕ), gross electron affinity (ϕ_g). (2) Angle (ϕ), angle of incidence (ϕ), angle of refraction (ϕ'), polarizing angle (ϕ), critical angle (ϕ_c). (3) Function of (ϕ). (4) Fluidity (ϕ). (5) Magnetic or radiant flux (Φ). (5) Electromagnetic scalar potential (ϕ). (7) Hydrodynamic velocity potential (ϕ). (8) Electronic state of molecule having Λ-value of 3 (Φ).

PHI (Φ) POLARIZATION. See **polarization, phi.**

PHON. The unit of **loudness level** of a sound, defined as numerically equal to the **sound pressure level** in **decibels,** relative to 0.0002 microbar, of a simple tone of frequency 1000 cycles per second which is judged by the listeners to be equivalent in loudness.

PHONETICS. The science of speech.

PHONOGRAPH. A system for the reproduction of sound from a record. The term usually refers to a system in which a stylus follows the undulations in the groove of a record and transforms these undulations into the corresponding acoustical or electrical variations

PHONOGRAPH, MECHANICAL. A mechano-acoustic **transducer** actuated by a phonograph record. By means of an acoustical system, the mechanical phonograph radiates acoustic energy into a room or open air.

PHONOGRAPH PICKUP (MECHANICAL REPRODUCER (PLAYBACK HEAD). A mechano-electrical **transducer** which is actuated by modulations present in the groove of the recording medium and which transforms this mechanical input into an electric output.

PHONOMETER, WEBSTER. A cylindrical **resonator** tunable by length variation over a wide range of frequencies with a tuned diaphragm mounted in the resonator opening. The pressure amplitude of the sound at the diaphragm is proportional to the displacement amplitude of the diaphragm. The device is used to measure sound intensity.

PHONON. A progressive wave in an **acoustic mode** of **thermal vibration** of a **crystal lattice** (or in liquid helium II). The theory of lattice vibrations is in many respects similar to that of the electromagnetic field, and it is convenient to introduce "particles," defined by **wave-packets**, moving through the medium with the **group velocity,** and capable of being annihilated, created, scattered, etc., by interaction with electrons and lattice imperfections. Like a **photon,** a **phonon** is quantized to have the energy $h\nu$, where ν is its vibrational frequency, and h is Planck's constant The concept of phonons allows a great formal simplification in theories of **thermal** and **electrical conduction** in solids.

PHONON - ELECTRON INTERACTION. See **scattering of electrons in solids.**

PHONON, LONGITUDINAL, OR TRANSVERSE. The **acoustic modes** of crystals fall into three distinct branches, which may be identified with the three types of **polarization** of the vibration, i.e., parallel to the **wave vector** (longitudinal), or in one of the two perpendicular directions normal to the **wave vector** (transverse). The actual polarizations are never exactly thus, except along certain symmetry directions in the crystal, but usually this assumption is a reasonable approximation. The distinction between the different types is not negligible in **phonon-phonon** and phonon-electron interactions.

PHONON MEAN FREE PATH. A quantity Λ defined from the **thermal conductivity** K of a dielectric solid, from its volume heat capacity C, and from the average velocity of sound v in the solid, by the formula

$$K = \tfrac{1}{3}Cv\Lambda.$$

Λ does indeed represent roughly the **mean free path** of a **phonon** as it carries thermal energy through the crystal, but it is not easy to assign to it an exact microscopic significance in terms of the various processes by which a phonon is scattered. However, in glasses, Λ has about the dimensions of the unit of structure (e.g., the SiO_2 tetrahedron), whilst in good crystals it varies as $e^{-\Theta/2T}$ at at low temperatures, according to the theory of **Umklapp processes.** In the region of **boundary scattering,** Λ is about the diameter of the specimen.

PHONON-PHONON INTERACTION. The **thermal vibrations** of a **crystal lattice** are only independent of one another as first approximation. When the **anharmonic terms** are taken into account, it is found that there are processes by which the modes interact, for example, by the mutual interference of two phonons to make a third. These "collisions," especially the **Umklapp processes,** are responsible for the thermal resistance of a dielectric solid at high temperatures. The exact theory is complicated, and has not been worked out in detail.

PHOSPHOR. Any substance which exhibits **luminescence.**

PHOSPHORESCENCE. **Luminescence** which is delayed by more than 10^{-8} seconds after excitation. It may be associated with transitions from a higher excited state to a lower one, the energy going into a radiationless rearrangement of the system. If the lower state is **metastable** its lifetime may be considerable before it finally decays by a highly **forbidden** radiative transition to the ground state. Another process (as in ZnS) depends on the ionization of **activator** atoms, the freed electrons being trapped and only released slowly for recombination.

PHOSPHORUS. Non-metallic element. Symbol P. Atomic number 15.

PHOT. A unit of **luminance** equal to 1 **lumen**/sq cm.

PHOTOCATHODE. An electrode used for obtaining photoelectric emission when irradiated, which is thus the irradiated negative electrode in a **phototube.** (See also **photoemissive effect.**)

PHOTOCELL. The old designation for all photoelectric devices, including those discussed in this book in the entries on **photoconductive detector, phototube** and **photovoltaic cell.**

PHOTOCELL, "GAS." See **phototube.**

PHOTOCONDUCTION. See **photoconductive effect.**

PHOTOCONDUCTIVE DETECTOR. Apparatus used to detect (and/or measure) **radiant energy** by change in electrical resistance. Semiconductors such as lead sulfide, lead selenide, lead telluride, germanium and many others, when doped with the proper amount of certain impurities, are used as radiation detectors, particularly in the near (1–10 microns) infrared because of their photoconductive properties.

PHOTOCONDUCTIVE EFFECT. Many substances exhibit a marked increase in electric conductivity when illuminated. Thus gases may be ionized by light as well as by ultra-violet radiation or x-rays. But the term photoconductivity is commonly applied to crystals which, ordinarily very poor conductors, become distinctly conducting under the action of light. In general terms, the light excites electrons into the conduction band, where they can move freely, and carry a current.

The most noted example of this phenomenon is found in selenium, whose photoconduc-

tivity has been known since its discovery in 1873 by May. Unfortunately selenium is far from typical in its manifestations of the property, and the hundreds of researches on it have given many conflicting data. It has finally been recognized, from the work of Gudden and Pohl, that photoconduction is of two general types: primary or true photoconduction, which is the direct result of radiation penetrating the substance; and secondary effects set up by the photoconduction itself. The fact that in selenium the several secondary effects quite obscure the primary photoconduction is what has occasioned so much confusion. The primary photoconduction current in a crystal is in general proportional to the intensity of the illumination; the secondary is not, and, in the case of "light-negative" selenium, it may actually neutralize the primary and render the crystal less conductive than when in the dark. Some crystals, said to be "idiochromatic," are photoconductive in the pure state, while others, called "allochromatic," acquire the property only by reason of impurities or of previous exposure to suitable radiation. Other representative photoconductive substances are lead sulfide and germanium.

PHOTOCURRENT COEFFICIENT. The change in photocurrent generated by a **phototube** per unit change in **radiant flux** producing it.

PHOTODISINTEGRATION (CROSS SECTION FORMULA). The cross section for the photodisintegration of the deuteron is given by:

$$\sigma = \frac{4}{3}\frac{hc^2}{mcE_0}\frac{\left(\dfrac{h\nu}{E_0} - 1\right)^{3/2}}{\left(\dfrac{h\nu}{E_0}\right)^3}$$

where E_0 is the binding energy of the deuteron (2.23 Mev) and $h\nu$ is the energy of the photon.

PHOTOELASTICITY. This badly chosen term refers to certain changes in the optical properties of isotropic, transparent dielectrics when subjected to stresses. For example, a block of glass, free from optical flaws, exhibits "forced" **double refraction** when put under compression or tension parallel to one of its dimensions. If the block is placed between crossed **Nicol prisms,** the field remains dark so long as the glass is in its normal condition, but as stress is applied, colored fringes appear which are characteristic of the internal deformations of the glass.

PHOTOELECTRIC ABSORPTION. Absorption of **photons** in the **photoelectric effect.**

PHOTOELECTRIC CELL. See **phototube.**

PHOTOELECTRIC CONSTANT. A quantity equal to h/e where h is the **Planck constant,** and e, the **electronic charge,** and which multiplied by the frequency of any radiation exciting photoemission gives the potential difference corresponding to the quantum energy absorbed by the escaping photoelectron.

$$\begin{aligned} h/e &= 4.1349 \times 10^{-7}\ \text{erg}\cdot\text{sec}\cdot\text{emu}^{-1} \\ &= 1.3793 \times 10^{-17}\ \text{erg}\cdot\text{sec}\cdot\text{esu}^{-1}. \end{aligned}$$

PHOTOELECTRIC EFFECT. In its earlier use, this term covered broadly all changes in electrical characteristics of substances due to radiation, generally in the form of light. Currently, the **photoconductive effect** and the **photovoltaic effect,** in their narrower meanings, are not included, and they are defined separately in this book, and the term photoelectric effect is restricted to the "photoemissive effect." In this effect, radiation of sufficiently high frequency, "short wavelength," impinging on certain substances particularly, but not exclusively, metals, causes bound electrons to be given off with a maximum velocity proportional to the frequency of the radiation, i.e., to the entire energy of the **photon.** The Einstein photoelectric law, verified first by Millikan, states

$$E_k = h\nu - \omega$$

where E_k is the maximum kinetic energy of an emitted electron, h is the **Planck constant,** ν is the frequency of the radiation (frequency associated with the absorbed photon), and ω is the energy necessary to remove the electron from the system. (See **work function, electronic.**)

PHOTOELECTRIC EFFECT, ATOMIC. The ejection of a **bound electron** from one of the inner orbits of an atom of a gas, by an incident photon whose entire energy is absorbed for each electron ejected. (See **Einstein photoelectric equation.**)

PHOTOELECTRIC EFFECT, INVERSE. Transfer of energy from electrons to radiation; for example, in an x-ray tube there is observed the transfer of energy from electrons accelerated by the anode voltage to radiation emitted by the target. This radiation exhibits a continuous spectrum at lower voltages, upon which are superimposed, at higher voltages, intense lines characteristic of the anode material. (See **x-rays, continuous,** and **x-rays, characteristic.**)

PHOTOELECTRIC EFFECT, SURFACE. When a bound electron is ejected from a solid or liquid in the **photoelectric effect** by an incident photon, and the entire energy of the latter is absorbed, the kinetic energy of the ejected electron is given by the formula,

$$E_k = h\nu - \omega$$

where E_k is the kinetic energy of the ejected electron, h is the Planck's constant, ν is the frequency associated with the absorbed photon, ω is the energy required to remove the electron from the system, or the **work function, electronic** for the surface of the metal.

PHOTOELECTRIC EMISSION. The phenomenon of emission of electrons by certain materials upon exposure to radiation, as discussed under **photoelectric effect.**

PHOTOELECTRIC EQUATION, EINSTEIN. See **Einstein photoelectric equation.**

PHOTOELECTRIC MULTIPLIER. A **phototube** in which the initial photoemission current is multiplied many times before being extracted at the anode (See **multiplier, phototube.**)

PHOTOELECTRIC SENSITIVITY. The ratio of photoelectric emission current to the radiant flux density which caused the emission.

PHOTOELECTRIC THRESHOLD. The quantum of energy $E_0 = h\nu_0$, which is just enough to release an electron from a given system in the **photoelectric effect.** If the incident photon has greater energy, the excess will appear as kinetic energy of the ejected electron. The frequency ν_0 is known as the threshold frequency and the corresponding wavelength λ_0, as the threshold wavelength. Thus, $E_0 = h\nu_0 = hc/\lambda_0$.

PHOTOELECTRIC WORK FUNCTION. The energy required to secure the release of electrons from a given surface by photoelectric emission. (See **photoelectric effect.**)

PHOTOELECTRIC YIELD. **Photoelectric sensitivity.**

PHOTOELECTROMOTIVE FORCE. The electromotive force produced as the result of photovoltaic action. (See **photovoltaic effect.**)

PHOTOELECTROMOTIVE FORCE CELL. See **photovoltaic cell.**

PHOTOELECTRON. An electron emitted from a material by photoemission (See **photoelectric effect.**)

PHOTOEMISSIVE DETECTOR. Apparatus used to detect (and/or measure) radiant energy by emission of electrons from a surface essentially a **photo-cathode**; the emitted electrons producing, or more commonly controlling, an electric current The emitted electrons may also be given a high velocity by a potential difference of several thousand volts, and by falling upon a phosphorescent screen, form an image This is a special type of **phototube** apparatus, particularly useful in the very near infrared and longer ultra violet.

PHOTOEMISSIVE EFFECT. The ejection of electrons from a substance as a result of radiation falling on it; a process more commonly designated by the (originally broader) term **photoelectric effect,** under which it is discussed in this book.

PHOTOEMISSIVE TUBE. See **phototube.**

PHOTOGLOW TUBE. A special form of **phototube** which has increased sensitivity by virtue of the glow initiated by light falling on the cathode.

PHOTOGRAPHIC IMAGE, LATENT. See **latent photographic image.**

PHOTOGRAPHIC SOUND RECORDER (OPTICAL SOUND RECORDER). Equipment incorporating means for producing a modulated light beam and means for moving a light-sensitive medium relative to the beam for recording signals derived from sound signals.

PHOTOGRAPHIC SOUND REPRODUCER (OPTICAL SOUND REPRODUCER). A combination of light source, optical system, photoelectric cell, or other light-sensitive device such as a photoconductive cell, and a mechanism for moving a medium carrying an optical sound record (usually film), by means of which the recorded variations may be converted into electric signals of approximately like form.

PHOTOGRAPHIC TRANSMISSION DENSITY (OPTICAL DENSITY). The common logarithm of **opacity.** Hence, film transmitting 100 per cent of the light has a density of zero, transmitting 10 per cent a density of 1, and so forth. Density may be diffuse, specular, or intermediate. Conditions must be specified.

PHOTOIONIZATION. See **photoelectric effect, atomic.**

PHOTO-ISLAND GRID. The photoemissive surface of an **image-dissector tube.**

PHOTOLUMINESCENCE. See discussion under **luminescence.**

PHOTOMESON. A **meson,** commonly a π-meson, ejected from a nucleus by an impinging photon.

PHOTOMETER. An instrument used to make measurements of photometry. Photometers are of many types Those used for flux-density and candle-power measurement are ordinarily designed to compare the unknown with a known source by balancing in some way the flux densities from the two sources. The most common representatives of this type are the various forms of **bench photometer,** of **wedge photometer,** of **polarization photometer,** and of **integrating photometer.** An important aspect of light-source photometry is the study of the distribution of luminous intensity in different directions—a variable which the integration photometer is designed to average. Direct indications of luminous flux density or of illumination are afforded by photometers utilizing the **photoelectric cell,** the **selenium cell,** or the photronic cell (see **photovoltaic effects**). **Spectral energy distribution** is analyzed by means of various types of **spectrophotometer.**

PHOTOMETER, EXTINCTION. See **extinction photometer.**

PHOTOMETER, FLICKER. See **flicker photometer.**

PHOTOMETER, INTEGRATING. See **integrating photometer.**

PHOTOMETER, MARTENS POLARIZATION. A **photometer** in which the beams of light from standard source and comparison source are split into two components by a **Wollaston prism,** one component from each beam then passes through an analyzing **Nicol prism,** so oriented when the photometric field is balanced, that it measures the relative **luminances** of the original beams.

PHOTOMETER, POLARIZATION. See **polarization photometer.**

PHOTOMETER, WEDGE. See **wedge photometer.**

PHOTOMETRIC STANDARD. One-sixtieth of the **luminance** of a **complete radiator** at the freezing point of platinum. (The luminance of such a complete radiator is 60 candles per square centimeter.)

PHOTOMETRY. The measurement of luminous intensity, of luminous flux density, or of **illumination** is known as photometry. The intensity of a light source may be expressed in candles or other arbitrarily defined source-units (see **candle power**), while luminous flux density and illumination are expressed in lumens per unit area of cross-section or of surface. A "lumen" is the amount of light or luminous flux received upon a unit surface, all points of which are at a unit distance from a concentrated source of one spherical candle intensity.

Since the energy of **radiation** is not at all equally stimulating to the optic nerve, we must recognize two different measures of its intensity: (1) the luminous flux density, in lumens per sq cm of cross-section, corresponding to the visual sensation evoked, and (2) the actual flow of power, in watts per sq cm, called the radiant flux density. The ratio of the one to the other for any wavelength is the "visibility factor" for that wavelength, while for the whole of any emission (all wavelengths) the corresponding ratio is called the **luminous efficiency** of the emission. The efficiency of a light source is expressed in lumens of visible output per watt of input power.

PHOTOMICROGRAPHY. The photography of objects with the **microscope.** It should be distinguished from microphotography, which is the term applied to production of small images. The apparatus for photomicrography consists of a light source, the microscope and a camera, all mounted on a rigid base.

PHOTOMULTIPLIER. (See **multiplier phototube.**)

PHOTONEGATIVE. Having decreasing conductivity with increasing radiation.

PHOTON. (1) A quantum of **electromagnetic energy.** The energy of a photon is $h\nu$, where h is the Planck constant, and ν is the frequency associated with the photon. The term photon usually refers to a plane-wave quantum of electromagnetic energy, for which the momentum is $h\nu/c$, and the component of angular momentum in the direction of the momentum is $\pm\hbar$ where c is the velocity of light and $\hbar$ is $h/2\pi$. (2) A name once given to the unit of visual stimulation now called the **troland.**

PHOTONEUTRON. A neutron emitted from a nucleus in a **photonuclear reaction.**

PHOTONUCLEAR REACTION. A **nuclear reaction** induced by a photon. In some cases the reaction probably takes place via a compound nucleus formed by absorption of the photon and distribution of its energy among the nuclear constituents; the nucleus may then "evaporate" one or more particles (see **spallation;** and **liquid-drop nuclear model**) or undergo **photofission.** In other cases the photon apparently interacts directly with a single nucleon, which is ejected as a **photoneutron** or **photoproton** without appreciable excitation of the rest of the nucleus.

PHOTOPHORESIS. A phenomenon in which a unidirectional motion is given, by a strong beam of light, to a system composed of very fine liquid or solid particles, which are suspended in a gas or falling through a vacuum.

PHOTOPOSITIVE. Having increasing conductivity as a result of increased radiation.

PHOTOPTIC VISION. Vision that takes place through the medium of the retinal **cones** occurs at moderate and high levels of **luminance** and allows distinction of colors.

PHOTOPROTON. A proton emitted from a nucleus in a **photonuclear reaction.**

PHOTOSENSITIVE. Exhibiting a **photoelectric effect.**

PHOTOTRANSISTOR. A thin wafer of germanium in which **holes** are generated by light absorption, and produce a multiplied photocurrent by **transistor** action at the **collector.**

PHOTOTROPY. A reversible isomeric change in solid substances attributable to the influence of light energy and accompanied by a color change.

PHOTOTUBE. An **electron tube** that contains a **photocathode,** and has an output depending at every instant on the total **photoelectric emission** from the irradiated area of the photocathode.

PHOTOTUBE, CAESIUM. A **phototube** with a caesium cathode

PHOTOTUBE, MULTIPLIER. A **phototube** with one or more **dynodes** between its **photocathode** and the output electrode. In general, the electrons emitted from the photocathode as a result of incident radiation are amplified by secondary emission (See **counter, scintillation.**)

PHOTOVARISTOR. A **varistor** in which the current-voltage relation may be modified by illumination, e.g., cadmium sulphide or lead telluride.

PHOTOVOLTAIC CELL. (1) Apparatus used to detect (and/or measure) **radiant energy** by generating a potential in the boundary (called the barrier layer) of an electrode consisting of two types of material, by the action of the radiant energy to be detected (See **detectors, infrared.**) (2) An electrolytic cell which sets up an electromotive force upon incidence of radiation, commonly light.

PHOTOVOLTAIC CELL, BECQUEREL. A photovoltaic cell having two identical electrodes, for example, silver electrodes coated with silver iodide, immersed in silver iodide solution Becquerel's early work with such cells, which produced an electromotive force and current only when illuminated, gave the name Becquerel effect to the photoelectric effect, or to this particular application of it.

PHOTOVOLTAIC CELL, COPPER-OXIDE. A **photovoltaic cell** utilizing the **barrier layer** between copper and cuprous oxide as the active area.

PHOTOVOLTAIC CELL, FRONT-WALL. A **photovoltaic** copper-copper-oxide **cell** in which the barrier layer lies at the boundary between top electrode and the cuprous oxide.

PHOTOVOLTAIC EFFECT. The production of an electromotive force by incidence of radiant energy, commonly light, upon the junction of two dissimilar materials, such as a ***p-n* junction** or metal-**semiconductor** junction.

PHOTOX CELL. Trade name for a common **photovoltaic cell.**

PHOTRONIC CELL. Trade name for one form of a **photovoltaic cell.**

PHYSICAL MAGNITUDES AND PHYSICAL EQUATIONS. Physics is a quantitative science, dealing primarily with things measurable and expressible in units. There are hundreds of these physical magnitudes, some simple, some requiring elaborate definition. Many obvious relations exist between them; for example, pressure (or any stress) is the ratio of a force to an area. Careful study reveals that most physical magnitudes have their measures so defined that they may be expressed in terms of not more than three elementary or fundamental magnitudes, combined in various ways. As to which magnitudes should be regarded as fundamental, custom has fixed the choice upon length, mass, and time; to which many physicists add magnetic permeability and dielectric constant, making five in all. In the **cgs system,** for example, the first three of these magnitudes are respectively represented by the centimeter, the gram, and the second, and all other physical units of the system except the magnetic and electric units are expressible in terms of these. Thus the unit of speed is 1 centimeter per second; of area, 1 square centimeter; of force (the dyne), 1 gram-centimeter per second per second; etc. This analysis may be generalized so as not to depend upon any specified system of units. Thus if length be denoted by L, mass by M, and time by T, the "dimension formula" for speed becomes L/T, for area L^2, for force ML/T^2, etc The derivation of such relationships, called "dimensional analysis," is a highly important item in theoretical physics.

In order that two physical quantities may be equal, or that one may be added to or subtracted from the other, it is obvious that they must have the same makeup and be expressible by the same combination of fundamental units. It follows that in an equation expressing relationship between physical magnitudes, both members and all terms of each member must have the same dimension formula. For example, the total area of a right circular cone of altitude h and having a base of radius r is $a = \pi r^2 + \pi r\sqrt{r^2 + h^2}$, each term of which has the dimension formula L^2 (since π is abstract). Again, the phase angle ϕ of an **alternating current** of frequency n (per second) in a circuit of resistance R (ohms), inductance L (henrys), and capacitance C (farads) is given by

$$\tan \phi = \frac{4\pi^2 n^2 LC - 1}{2\pi nRC}.$$

Since $\tan \phi$ is an abstract quantity, the fraction on the right must also be abstract. Since the 1 in the numerator is abstract, the other term $4\pi^2 n^2 LC$ and the whole numerator must be also; hence the denominator is abstract. That is n, R, and C should have such dimensions that the component fundamental magnitudes cancel when the product nRC is formed. This is true; for the dimension formula of n is $1/T$, and (in electromagnetic measure) that of R is $\mu L/T$, and of C, $T^2/\mu L$; in which μ represents magnetic permeability. Some physical magnitudes are themselves abstract, and therefore independent of the system of units in use; **specific gravity** and **refractive index** are in this class.

PHYSICAL MASS UNIT. See **amu.**

PHYSICAL MEASUREMENTS. Physical quantities have practical significance only as they are capable of measurement and of expression as bearing definite numerical ratios to appropriate units In some cases this comparison can be made directly, as by applying a yardstick to the length of a room. More often the quantity to be measured is incapable of such direct attack, and must be determined by means of known relationships to other quantities which are observable. Thus an electric current can be measured only by appealing to certain of its effects; for example, it can be made to form an electrochemical

deposit for an observed time and the mass of the deposit then weighed. Likewise, the observable change in volume of mercury is a convenient "measure" of change in temperature.

Most physical units are expressible in terms of certain primary standards, which are units of the fundamental magnitudes, length, mass, and **time**; sometimes in connection with the properties of specified substances In most physical measurements these primary standards are the **meter,** the **kilogram,** and the mean solar day. Other "derived" units are defined in terms of these or of multiples or aliquot subdivisions of them (**centimeter, gram;** see **cgs system**) Thus the **density** of a substance may be expressed in g/cm^3, the **watt** of power is 10^7 g cm^2 sec^3 The centigrade degree is $\frac{1}{100}$ of the temperature interval between the freezing and boiling points of water, which is subdivided on the basis of some specified temperature measure such as the pressure or the volume of a gas, the electrical resistance of a wire, etc , and these in turn must be determined in units appropriate to the respective magnitudes When the measurement of a physical quantity gives its value in terms of the quantities used in defining its fundamental units, the measurement is said to be "absolute" This is the case, for example, with the measurement of electric current by observing the **force** with which **a magnetic field** of known intensity acts upon the conductor carrying the current (See **abampere.**)

In all physical measurements, the instruments used must be "calibrated"; that is, the relation of each subdivision on the instrument scale to the unit of the quantity measured must be ascertained If each subdivision corresponds to exactly one unit, the instrument is said to be "direct reading"; this is usually true, for example, of **ammeters** and **voltmeters,** but seldom of **galvanometers.**

Various instrumental principles have become standard in physics We have, for example, many instruments utilizing the **vernier,** the **micrometer,** or the **optical lever** principle There are also certain well-known general observational methods, some of which are designed to minimize errors. In the method of "substitution," a quantity is determined by substituting for it a known quantity which produces the same effect. In the very common "differential method," the quantity required is the difference between two actually measured quantities. The "null" or "balance" method consists in adjusting the apparatus so that the indicator of the measuring instrument reads zero, as the galvanometer used with a **Wheatstone bridge.** In the "cumulative method" a large multiple of the quantity sought is measured, e g., the thickness of a sheet of paper may be found from that of a thousand sheets The "coincidence method" is useful in measuring periodic phenomena, as in comparing the periods of two pendulums by observing how often the swings coincide "Compensation" applies to any method in which an error is made to neutralize itself, as in double weighing (see **weighing methods**) Many other schemes, often highly ingenious, are in common use in physical laboratories (See **error** and entries immediately following)

PHYSIOLOGICAL ACOUSTICS. That part of acoustics which is concerned with the production and detection of sound by living organs

PI. (1) The ratio of the circumference of a circle to its diameter (π) (2) Peltier coefficient (Π). (3) Hertzian vector (Π). (4) Poynting vector (π) (5) Electronic state of molecule, having Λ-value of 1 (Π) (6) Osmotic pressure (Π)

PI NETWORK. See **network, pi.**

PICARD METHOD OF SUCCESSIVE APPROXIMATIONS OR ITERATION. A **numerical method** for solving differential equations. If the given equation is $y' = f(x,y)$ subject to the condition that $y = y_0$ when $x = x_0$, the solution may be written in the form of an integral equation

$$y = y_0 + \int_{x_0}^{x} f(x,y)dx.$$

An approximate solution is

$$y_1 = y_0 + \int_{x_0}^{x} f(x,y_0)dx.$$

Iteration yields more exact solutions:

$$y_2 = y_0 + \int_{x_0}^{x} f(x,y_1)dx; \cdots$$

$$y_n = y_0 + \int_{x_0}^{x} f(x,y_{n-1})dx.$$

PICK OFF CIRCUIT. The name sometimes applied to a **bistable multivibrator** or trigger circuit.

PICKUP. (1) A device that converts a sound, scene, or other form of intelligence into corresponding electric signals (e.g., a **microphone**, a **television camera**, or a **phonograph pickup**). (2) The minimum current, voltage, power, or other value at which a relay will complete its intended function. (3) Interference from a nearby circuit or system. (4) A **nuclear reaction** in which an incident particle removes a **nucleon** from a target nucleus, and proceeds with the nucleon bound to itself.

PICKUP, ACOUSTIC (SOUND BOX). A device which transforms **groove modulations** directly into acoustic vibrations.

PICKUP, CAPACITOR. (1) A phonograph or vibration **pickup** whose **transducer** functions basically as a capacitor microphone. (2) A variable-capacity pickup in which the capacitance variation causes an **oscillator** to be frequency-modulated.

PICKUP, CRYSTAL (PIEZOELECTRIC PICKUP). A **phonograph pickup** which depends for its operation on the generation of an electric charge by the deformation of a body (usually crystalline) having **piezoelectric** properties.

PICKUP, DYNAMIC. See **pickup, moving coil.**

PICKUP, ELECTRONIC. A **phonograph pickup** in which the output is generated by the motion of an electrode in a vacuum tube.

PICKUP, FREQUENCY MODULATION. A **phonograph pickup** in which the frequency of a high frequency oscillator is varied by altering one of the elements in the oscillating circuit. By use of a **discriminator** the modulated high frequency output is transformed to the vibration frequency of the stylus.

PICKUP, MOVING-COIL (DYNAMIC REPRODUCER). A **phonograph pickup**, the electric output of which results from the motion of a conductor or coil in a magnetic field.

PICKUP SPECTRAL CHARACTERISTIC. The set of spectral responses of the device, including the optical parts, which converts radiation to electric signals prior to any **non-linearizing** and **matrixing** operations.

PICKUP TUBE. See **tube, camera.**

PICKUP, VARIABLE-INDUCTANCE. A **phonograph pickup** which depends for its operation on the variation of its inductance.

PICKUP, VARIABLE - RELUCTANCE (MAGNETIC PICKUP). A **phonograph pickup** which depends for its operation on the variation in the **reluctance** of a magnetic circuit.

PICKUP, VARIABLE-RESISTANCE. A **phonograph pickup** which depends for its operation upon the variation of a resistance.

PICKUP, VIBRATION. A pickup employing any type of **transducer** to convert the vibratory motion of machinery, vehicles, etc., into the corresponding electrical current.

PICTET METHOD. See **low temperature.**

PICTURE ELEMENT. In television, (1) the smallest portions of an image that are distinguishable from each other; or (2) a segment of a **scanning line,** the dimension of which along the line is exactly equal to the nominal line width. (See **line width, nominal.**)

PICTURE SIGNAL. In television, the signal resulting from the **scanning** process.

PICTURE SIGNAL, POLARITY OF. The sense of the potential of a portion of the **signal** representing a dark area of a scene relative to the potential of a portion of the signal representing a light area. Polarity is stated as "black negative" or "black positive."

PICTURE TRANSMISSION, D-C. See **d-c picture transmission.**

PICTURE TRANSMITTER. See **transmitter, visual.**

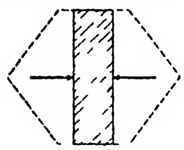
PICTURE TUBE. See **kinescope.**

PIERCE OSCILLATOR. See **oscillator, Pierce.**

PIEZOELECTRIC EFFECT. The interaction between electrical and mechanical stress-strain variables in a medium. Thus, compression of a crystal of quartz or Rochelle salt generates an electrostatic voltage across

it, and conversely, application of an electric field may cause the crystal to expand or contract in certain directions. Piezoelectricity is only possible in crystal classes which do not possess a **center of symmetry.** Unlike **electrostriction,** the effect is linear in the field strength.

The directions in which tension or compression develop polarization parallel to the strain are called the piezoelectric axes of the crystal. Thus the axis of a hexagonal quartz crystal indicated by the arrows in the figure is known



as an "X-axis," and a plate cut, as shown, with its faces perpendicular to this direction is an "X-cut"; while one cut with its faces parallel to the lateral faces of the crystal is a "Y-cut."

The magnitude of the piezoelectric polarization is proportional to the strain and to the corresponding stress, and its direction is reversed when the strain changes from compression to tension. The principal piezoelectric constants of a crystal are the polarizations per unit stress along the piezoelectric axes. While these constants are much greater for Rochelle salt than for quartz, the latter is better adapted to some purposes because of its greater mechanical strength and its stability at temperatures over 100°C.

PIEZOELECTRIC EFFECT, DIRECT. The production of electric charges on the faces of certain asymmetric crystals when they are subjected to mechanical stress.

PIEZOELECTRIC EFFECT, INVERSE. The mechanical strain produced in certain asymmetric crystals when they are placed in an electric field.

PIEZOELECTRIC EFFECT, QUADRATIC. A strain in a crystal caused by a spontaneous **polarization,** or an applied field acting on a piezoelectric crystal.

PIEZOELECTRIC LOUDSPEAKER. See **loudspeaker, crystal.**

PIEZOELECTRIC MICROPHONE. See **microphone, crystal.**

PIEZOELECTRICITY. Electricity associated with the **piezoelectric effect.**

PIEZOID. A finished piezoelectric crystal product after the completion of all processes; this may include electrodes adherent to the crystal. (See **piezoelectric effect.**)

PIEZOID, RESONATING. A **piezoid** used as a **resonator** or **oscillator.**

PIEZOID, TRANSDUCING. A **piezoid** used in a **transducer.**

PIEZOMETER. An instrument for measuring pressure, particularly very high pressures.

PIEZOMETER RING. A hollow ring surrounding a pipe to which it is connected by several symmetrically spaced small holes so that the pressure in the ring is the average of the various values obtained at the holes in the pipe. A **piezometer,** or other pressure-measuring device, is connected to the ring to measure this average pressure.

PIEZOMETER TUBE (OR STATIC PRESSURE TUBE). A tube inserted in a field of flow and designed to lead off a pressure equal to the local hydrostatic pressure. A small flush opening in the wall of a pipe will measure the pressure at the wall, but more care is necessary before the pressure in a free stream can be measured. The static tube, which is a smooth-ended tube pointing into the flow and communicating with it by a ring of small flush holes some distance from the end, is often used for this purpose.

PILE. A nuclear reactor (see **reactor, nuclear**). The term pile comes from the first nuclear reactor, which was made by piling up graphite blocks and pieces of uranium and uranium oxide. The term reactor is becoming more commonly used.

PILE OF PLATES (POLARIZING). When a beam of light impinges on a glass plate at the **Brewster angle,** the light is partly reflected and partly transmitted. The part reflected is plane-polarized. The part transmitted is partly polarized, normal to the reflected polarization. By then passing the transmitted light through another plate, it becomes more fully plane-polarized. A number of such passages through plates gives excellent polarization. This method of polarization can be applied to a beam larger than is practicable with a **Nicol prism** or other similar polarizing device, and does not heat as much as does polaroid material.

PILE, THERMO-. A series of **thermocouples,** i e., junctions of two metals arranged so that their contact **potential difference** yields a measurable current, as by connecting them in a circuit which contains two contact points, at different temperatures, between the two metals.

PILED-UP GROUP. A row of **edge dislocations** moving along the same **slip plane,** but arrested by an obstacle (e g , **grain boundary**) behind which they pile up, being held apart by their mutual repulsion.

PILL-BOX ANTENNA. See **antenna, pill-box.**

PILOT SPARK. A low-power spark used to create **ionization** to prepare the way for a larger discharge. The keep-alive electrode in a TR tube (see **tube, TR**) is one example of the pilot spark.

PILOT WIRE REGULATOR. The automatic regulation of the **gain** of long telephone cables, etc., with a system which employs a temperature-sensitive wire inside the cable as an average-temperature sensing element.

PING. A pulse of sound of finite duration sent out by a **transducer.**

PING LENGTH. The extension in space of a single **ping.** It is equal to the product of the sound velocity and the time duration of the ping

PINHOLE "IMAGE." If a small opening is made in one side of a darkened room or box, an inverted picture of objects outside appears upon the wall opposite the opening Such a

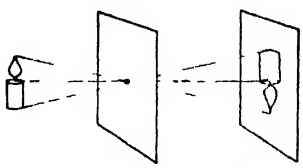


Diagram showing formation of pinhole "image"

picture differs from a true image in that it is not formed by light from a given point of the source diverging and being reconverged at the corresponding image-point, as by a lens, but is an effect of the rectilinear propagation of light. The only spot on the screen reached by light from a given point of the source is that in direct line with the opening

PION. A π-meson. (See **meson.**)

PIP. Colloquialism for a peaked pattern on a **cathode-ray tube,** especially that due to a **radar** signal.

PIPE LINE. Colloquialism for **coaxial cable.**

PISTONPHONE. A small chamber equipped with a reciprocating piston of measurable displacement which permits the establishment of a known sound pressure in the chamber.

PITCH. (1) That attribute of auditory sensation in terms of which sounds may be ordered on a scale extending from low to high, such as a musical scale Pitch depends primarily upon the frequency of the sound stimulus, but it also depends upon the sound pressure and wave form of the stimulus. The pitch of a sound may be described by the frequency of that simple tone, having a specified **sound pressure** or **loudness level,** which seems to the average normal ear to produce the same pitch (2) See **pitch of screw.**

PITCH DIFFERENCE, MINIMUM PERCEPTIBLE. The smallest difference in **pitch** that can be discerned by the average single ear

PITCH LEVEL. The pitch level P is given by

$$P = A \log_2 f,$$

where P is in octaves, f in kilocycles and A is a constant

PITCH OF SCREW. Axial distance between adjacent turns of a single thread on a screw.

PITCH, STANDARD. The standard pitch is based on the tone "A" of 440 cycles per second With this standard the frequency of Middle C (located in the octave below the tone "A") is 261 6 cycles per second. Musical instruments should be capable of complying with this standard when played where the ambient temperature is 22°C (72°F).

PITOT TUBE. An open-ended tube usually of circular section pointing directly into the flow of a fluid and connected to a **manometer.** If the **Reynolds number** based on tube diameter and flow velocity exceeds 50, the pressure in the tube equals the total head (see **head, total**) The Pitot tube is often combined with a static pressure tube and connected to a dif-

ferential manometer The pressure difference measured is the dynamic pressure and from this the flow velocity may be computed.

PITOT-STATIC TUBE. The instrument for the measurement of flow velocity made by combining in one unit a **Pitot tube** and a static head tube If the Pitot-static tube is aligned with the flow, the pressure difference equals the dynamic pressure

PLAIT POINT. The point at which two **conjugate solutions** of partially miscible liquids have the same composition, so that the two layers become one

PLANAR NETWORK. See **network, planar.**

PLANCK CONSTANT. A universal constant, h, that has the value, by least squares adjusted output values of 6 62377 + 0 00018 $\times 10^{-27}$ erg second It is the factor of proportionality relating the energy of a photon to its frequency, i e, $E = h\nu$

PLANCK DISTRIBUTION LAW. See **Planck radiation formula.**

PLANCK EQUATION. See **Planck radiation formula.**

PLANCK LAW. The fundamental law of the **quantum theory,** expressing the essential concept that energy transfers associated with radiation such as **light** or **x-rays** are made up of definite quanta or increments of energy proportional to the frequency of the corresponding radiation This proportionality is usually expressed by the quantum formula $E = h\nu$, in which E is the value of the quantum in units of energy and ν is the frequency of the radiation

h, the constant of proportionality, is known as the elementary quantum of action or more commonly, the **Planck's constant.** Since E is energy and ν is frequency, h has the dimensions of energy $\times$ time, or **action.**

PLANCK RADIATION FORMULA. The relationship:

$$E_\lambda d\lambda = \frac{hc^3}{\lambda^5}\frac{d\lambda}{e^{\frac{hc}{k\lambda T}} - 1}$$

where $E_\lambda d\lambda$ is the intensity of radiation in the wavelength band between λ and $\lambda + d\lambda$, h is the **Planck constant,** c is the velocity of light, k is the **Boltzmann constant** and T is the absolute temperature This formula describes the spectral distribution of the radiation from a complete radiator or "black body." $hc^3 = C_1$ is known as the First Radiation constant with $ch/k = C_2$ as the Second Radiation constant. C_2 has the value 1 1384 cm deg This radiation formula can be written in other forms, such as in terms of wave-number instead of wavelength Also it may be written in terms of energy density instead of radiation intensity. The value of the First Radiation constant will depend on the particular form of the radiation formula used

PLANCKIAN COLOR. The color or wavelength-intensity distribution of the light emitted by a **black body** at a given temperature

PLANCKIAN LOCUS. The locus of **chromaticities** of Planckian (**black body**) radiators having various temperatures (See figure in definition of **chromaticity diagram.**)

PLANCKIAN RADIATOR. A **complete radiator.**

PLANE. A **surface** on which any two points may be connected by a straight line Its general equation is $Ax + By + Cz + D = 0$, with A, B, C not all zero Thus the locus of every first degree equation in x, y, z is a plane Other forms of its equation are $x/a + y/b + z/c = 1$, where a, b, c are the x, y, z-intercepts and the normal form $\lambda x + \mu y + \nu z = p$, where λ, μ, ν are **direction cosines** of the **normal** from the origin to the plane and p is the length of this normal

PLANE EARTH FACTOR. The ratio of the **electric field strength** that would result from **propagation** over an imperfectly-conducting plane earth, to that which would result from propagation over a perfectly-conducting plane

PLANE OF POLARIZATION. See **polarization, plane of.**

PLANE OF SYMMETRY. An imaginary plane by which a body is divided into two parts, each of which is the exact mirror image of the other in the plane of symmetry.

PLANE OF VIBRATION. If a ray of unpolarized light strikes a glass plate at the **Brewster angle** (tan $i = n$), the reflected light will be plane-polarized The plane of **polarization** is the plane containing the incident ray, the reflected ray and the normal to the

surface. The "plane of vibration" is a plane containing the reflected ray (i.e., the plane-polarized ray) and normal to the plane of polarization. The electric vector of the plane-polarized light lies in the plane of vibration. The magnetic vector of the plane-polarized light lies in the plane of polarization. If the incident ray is itself plane-polarized, it will be reflected if its plane of polarization is in the plane of incidence, or in other words, if its plane of vibration is the normal to the plane of incidence. If, however, its plane of vibration is in the plane of incidence there will be a minimum of reflection.

PLANE-POLARIZED LIGHT. See **light, plane-polarized.**

PLANE-POLARIZED SOUND WAVE. See **sound wave, plane-polarized.**

PLANE-POLARIZED WAVE. See **wave, plane-polarized.**

PLANE WAVE. See **wave, plane.**

PLANETARY ORBIT THEORY. The motions of the planets are described, to a high degree of accuracy, by the **laws of Kepler.** The consistency of these laws with the inverse square law (cf **gravitation, Newton law of universal**) is the major basis of support of the latter. In accordance with the discussion given under **Coriolis effects,** the differential equations of motion are

$$m\frac{d^2r}{dt^2} = -\frac{GmM}{r^2} + mr\left(\frac{d\theta}{dt}\right)^2,$$

$$mr^2\frac{d^2\theta}{dt^2} = -2mr\frac{dr}{dt}\frac{d\theta}{dt}$$

where G is the **gravitation constant,** m is the **reduced mass** of the planet, M is the mass of the sun, r and θ are the **polar coordinates** of the planet with the sun as origin. A single integration of the second equation yields the second law of Kepler. The substitution of $r^2(d\theta/dt) = C$ (a constant) into the first equation and an elimination of the time shows that the orbits are **conic sections,** being ellipses if the total energy is less than zero, hyperbolae if it is greater than zero and parabolae in the intermediate case. Reinsertion of the time leads to Kepler's third law.

All of the above treatment assumes that no bodies other than the sun affect the planet. No exact solution of the problem is possible when the effects of neighboring planets, satellites, etc., are taken into account, but **perturbation theory** may be used to obtain very close approximations. The agreement of theory and experiment has been excellent except in the case of Mercury, whose orbit is not quite that predicted (see **perihelion of Mercury, rotation of**). The fact that this exceptional case agrees with the prediction of the general theory of relativity (see **relativity, general theory of**), indicates that this theory offers a better approach than does the Newton law of gravitation, although the two theories agree within the observational accuracy for all of the other planets.

PLANIMETER, POLAR. An instrument for measuring the area enclosed within a given closed contour or under a given curve; thus, a device for evaluating a definite integral, numerically.

PLASMA. The region in a **gas discharge** which contains very nearly equal numbers of positive ions and electrons, and hence is nearly neutral.

PLASMATRON. A continuously-controllable **gas-discharge tube** which utilizes an independently-generated gas-discharge **plasma** as a conductor between a hot cathode and an anode. Continuous **modulation** of the anode current can be effected by variation either of the conductivity or the effective cross-section of the plasma. The first method is based upon the modulation of the electron-ionizing beam which controls the plasma density, and hence its conductivity. The second method makes use of the **gating** action of positive-ion sheaths which surround the wires of a **grid,** located between the anode and cathode.

PLASTIC DEFORMATION. If sufficient **stress** is applied to a solid it may not return to its original condition when the stress is removed. The theory of plasticity is extremely complicated, but in the case of metals much progress has recently been made by the introduction of the idea of **dislocations.** The **shear strength** of **single crystals** is unexpectedly small, but increases by **work-hardening.**

PLASTICITY. A property of certain types of matter in which the deformation resulting from a particular stress is retained to a large extent even after the removal of the stress. This is in distinction to **elasticity.**

PLASTICITY, INVERSE. See **dilatancy.**

PLATE. A common name for the principal anode in an electrode tube

PLATE CHARACTERISTIC. See **electrode characteristic.**

PLATE CURRENT. See **electrode current.**

PLATE DETECTOR. See **detector,, balanced.**

PLATE DISSIPATION. The power loss occurring at the **plate** of an electronic **tube,** which is of considerable importance in high-voltage vacuum tubes The **electrons** in traversing the space between electrodes under the influence of the applied voltage acquire kinetic energy which must be dissipated when the electron is brought to rest upon striking the plate. This power is equal the product of the plate current and plate voltage (it should be noted that this is the voltage at the plate and not necessarily the voltage applied to the circuit since there is usually a drop in the load).

PLATE (ANODE) EFFICIENCY. The ratio of load circuit power (alternating current) to the plate power input (direct current).

PLATE KEYING. See **keying, plate.**

PLATE (ANODE) LOAD IMPEDANCE. The total impedance between anode and cathode exclusive of the **electron stream.**

PLATE (ANODE) MODULATION. See **modulation, plate (anode).**

PLATE NEUTRALIZATION. See **neutralization, plate.**

PLATE (ANODE) POWER INPUT. The direct-current power delivered to the plate (anode) of an **electron tube** by the source of supply. It is the product of the mean anode voltage and the mean anode current.

PLATE (ANODE) PULSE MODULATION. See **modulation, plate (anode) pulse.**

PLATE RESISTANCE. One of the vacuum-**tube** coefficients which is used in analyzing the behavior of the tube in a circuit Mathematically it is expressed as

$$r_p = \left.\frac{de_p}{di_p}\right] \qquad (E_g \text{ constant})$$

where de_p and di_p represent infinitesimal changes of plate voltage and current and E_g is the grid voltage.

The value of the plate resistance, or, more properly, the dynamic plate resistance, is essentially constant over the normal operating range of the tube but is dependent upon the electrode voltages. From the equation it may be seen that it is the reciprocal of the slope of the plate current-plate voltage characteristic curve of the tube. In developing the equivalent circuit of the vacuum tube the plate resistance is the value used for the internal resistance of the equivalent **generator.**

PLATE SATURATION. See **current saturation; voltage saturation;** and **temperature saturation.**

PLATE SUPPLY. The power source, usually d-c, for the plate circuit of an **electron-tube** device. (See **plate input power.**)

PLATE VOLTAGE. See **electrode voltage.**

PLATEAU (COUNTER). The portion of the **counting rate** versus **voltage** characteristic curve in which the counting rate is substantially independent of the applied voltage

PLATEAU LENGTH (COUNTER). The range of applied voltage over which the **plateau** of a radiation **counter tube** extends.

PLATEAU SLOPE, NORMALIZED. A **figure of merit** for a radiation **counter tube,** the percentage change in counting rate divided by the percentage change in voltage, using the threshold values as a base

PLATEAU SLOPE, RELATIVE. The average percentage change in the counting rate near the mid-point of the **plateau** per increment of applied voltage. Relative plateau slope is usually expressed as the percentage change in counting rate per 100-volt change in applied voltage.

PLATINUM. Metallic element. Symbol Pt. Atomic number 78.

PLAYBACK. Reproduction of a **recording.**

PLEOCHROIC HALO. A small spherical or (as usually observed in section) circular colored or darkened region surrounding a fragment of an α-emitting radioactive substance embedded in mica and other transparent minerals. The color is due to crystal

damage caused by the **α-particles,** and the radius of the halo is equal to their range in the material, which is 10 to 50 microns in most minerals. The ring-like appearance results because an α-particle produces a maximum of ionization (and therefore of darkening) near the end of its range. Frequently a multiple, concentric halo is observed, corresponding to emission of α-particles of differing ranges in successive transformations in a **radioactive series.**

PLEOCHROISM (PLEOCHROMATISM). The property possessed by certain crystals of exhibiting different absorption colors as viewed in the direction of the different crystal axes. Iolite, a silicate of aluminum, iron and magnesium shows this property strongly.

PLEOMORPHISM. The property of crystallizing in two or more forms. The term includes dimorphism and trimorphism. (Cf. **polymorphism.**)

PLIOTRON. The name sometimes applied to a high-vacuum tube which has one or more **grids.**

PLUGGING. A system of dynamic braking which changes the drive motor in such a manner that it tends to turn in the opposite direction.

PLUMBING. Colloquialism for **waveguide** or rigid **coaxial lines** and fittings.

PLURAL SCATTERING. See **scattering, plural.**

PLUTONIUM. Transuranic element. Symbol Pu. Atomic number 94.

P-M. (1) Abbreviation for permanent **magnet.** (2) Abbreviation for **phase modulation.**

PNEUMATIC. Related to, or pertaining to, air or derivatively to other gases. Thus, a pneumatic trough is a small tank, containing a shelf with small holes. It is used to collect gases in the laboratory, by pouring water into it to a level above the shelf, on which are placed inverted gas-collecting bottles filled with water, which is displaced from them by gas from tubes passing under the shelf and into the bottles through the holes in the shelf.

PNEUMATIC LOUDSPEAKER. See **loudspeaker, pneumatic.**

POGGENDORFF COMPENSATION METHOD. A method of determining the **electromotive force** of a cell without drawing appreciable current, by balancing its potential against the voltage drop across a portion of a uniform resistance wire, and comparing that with the corresponding measurement for a standard cell. (See **potentiometer.**)

POIDOMETER. An apparatus for determining large masses (weights) rapidly. It is used extensively in industry.

POINCARÉ ELECTRON THEORY. Classical model of the electron in which the particle is held together by non-electromagnetic forces, thereby giving a vanishing self-stress. The model is unstable, however, and gives an infinite **self-energy** for a point electron.

POINSOT MOTION. See **polhode; herpolhode.**

POINT CONTACT OF A SEMICONDUCTOR. Pressure contact between a **semiconductor** body and a metallic point.

POINT GROUP. One of the 32 different **symmetry classes** to which a crystal may belong, in virtue of the occurrence of different elements of symmetry passing through a single point, together with the necessity of obeying the **Haüy law** of rational indices.

POINT IMAGES. See **images, point.**

POINT-OBSERVER. Idealized concept used in relativity theory of an observer equipped with measuring-rods and a clock and imagined as being located at a point.

POINT SOURCE. No finite source of radiation is a true point, but any source viewed from a distance sufficiently great compared to the linear size of the source may be considered as a point source. In the distance range in which measurements of the radiation from a source show that it obeys the **inverse square law** (no absorption), then to the accuracy of the measurements, the source may be considered as a point source.

POISE. A unit of coefficient of **viscosity,** defined as the tangential force per unit area (dynes/cm^2) required to maintain unit difference in velocity (1 cm/sec) between two parallel planes separated by 1 cm of fluid; 1 poise = 1 dyne sec/cm^2 = 1 gm/cm sec.

POISEUILLE EQUATION. A relation between the volume flow along a cylindrical tube and the pressure difference between the ends:

$$V = \frac{\pi}{8}\frac{pr^4}{\eta l}$$

where V is the volume flow, p is the pressure difference, r is the internal radius of the tube, l is the length of the tube, η is the fluid viscosity. It is only valid if the flow is laminar, which may not be true if the flow **Reynolds number** $Vp/\pi r\eta$ exceeds 2000. This equation is the basis of standard methods of measuring fluid **viscosities.**

POISON. (1) In a nuclear **reactor,** any substance which absorbs neutrons without leading to **fission.** Poisons are generally structural materials and impurities in the **moderator** and fuel; they may on occasion be introduced into the reactor for purposes of safety or control. (2) A material which reduces the phosphorescent sensitivity of a **phosphor.** (3) A material which reduces the emission capabilities of a **cathode.**

POISONING OF A REACTOR. The ratio of the number of thermal neutrons (see **neutrons, thermal**) absorbed by **poison** to those absorbed in fuel.

POISSON BRACKET. Let X,Y be two dynamical variables which depend on canonically conjugate variables like p,q, momentum and position, respectively, then the Poisson bracket is defined as

$$[X,Y] = \frac{\partial X}{\partial q_i}\frac{\partial Y}{\partial p_i} - \frac{\partial Y}{\partial q_i}\frac{\partial X}{\partial p_i},$$

it being understood that the right-hand member is to be summed over all degrees of freedom of the system. The Poisson brackets are useful in both classical and quantum mechanics. Dynamical systems described in terms of them are invariant to canonical transformations. In **quantum mechanics**

$$[A,B] \equiv \frac{-i}{\hbar}(AB - BA).$$

POISSON EQUATION. An inhomogeneous analogue of the **Laplace equation,** a partial differential equation of the form

$$\nabla^2\phi = f(x,y,z).$$

It occurs in (1) electrostatics (see **Poisson equation** in electrostatics); (2) thermal conduction, where ϕ is the temperature in a homogeneous medium of thermal conductivity κ and in which $A(x,y,z)$ calories of heat are generated per unit of volume and time, so that $f(x,y,z) = -A/\kappa$.

POISSON EQUATION IN ELECTROSTATICS. The differential equation describing the electric field (E) or the potential (ϕ) produced by a distribution of charge density (ρ):

$$\nabla\cdot\mathbf{E} = -\nabla^2\phi = \rho/\epsilon$$

in rationalized **mksa units,** or

$$\nabla\cdot\mathbf{E} = -\nabla^2\phi = 4\pi\rho/\kappa$$

in unrationalized **esu.** These two forms of the equation apply if the medium is homogeneous and isotropic. Otherwise

$$\nabla\cdot\mathbf{D} = \nabla\cdot(\epsilon\mathbf{E}) = \begin{cases}\rho \\ 4\pi\rho\end{cases}$$

POISSON RATIO. The ratio of the contraction in the direction of the axis of y to the extension in the direction of the axis of x for a sample subjected to the stress X_x. For an isotropic solid, Poisson's ratio, σ, is given by

$$\sigma = \frac{\lambda}{2(\lambda + \mu)}$$

where μ is the **rigidity,** and $\lambda + \frac{2}{3}\mu$ is the **modulus of compression.**

POLAR. Having, or pertaining to, a pole, or one of two ends of an axis of rotation, and (derivatively) one of two regions of antithetical properties.

POLAR COORDINATES. If r is the distance from the origin of a **rectangular Cartesian coordinate system** to a point (x,y,z) and if the direction angles of a line drawn from the origin to the point are α,β,γ then the **polar coordinates** of the point are given by

$$x = r\cos\alpha;\quad y = r\cos\beta;\quad z = r\cos\gamma;$$
$$r^2 = x^2 + y^2 + z^2.$$

Further relations also exist and the system is generally called **spherical polar coordinates.**

If the point lies in a plane determined by a pair of the coordinates, the XY-plane for

instance, then $z = 0$, and with the usual symbols, $\alpha = \beta = (\pi - \theta)$

$$x = r \cos\theta; \quad y = r \sin\theta, \quad \theta = \tan^{-1} y/x.$$

The coordinate origin is called the **pole;** the X-axis is the **polar axis;** the angle θ is the **polar** or **vectorial angle** (sometimes the **azimuth** of the point); r is the **radius vector. Complex numbers** are often plotted in this way, the vectorial angle then being called the **amplitude, argument** or **phase** and the radius vector is the **modulus.**

POLAR MOLECULE. A molecule that has an electrical **dipole moment,** because of the presence in its structure, commonly, of polar valence bonds, such as bonds between atoms which differ in their attraction for shared electrons.

POLAR POTENTIOMETER. See **potentiometer, polar.**

POLARIMETRY. Measurement of the rotation of the plane of polarization of **polarized light.**

POLARISCOPE. An instrument for ascertaining the properties of **polarized light** or for studying the effects of various agencies upon light of known polarization It ordinarily consists of a "polarizer" for rendering common light plane-polarized in any desired azimuth, and an "analyzer" for identifying the character of polarized light; between the e is usually a mounting for objects whose effect upon the light from the polarizer it may be desired to test. For example, the polarizer may be a **Nicol prism** from which the light emerges vibrating, say, in a horizontal plane; the analyzer may be another, similar Nicol; and between them may be mounted a tube with glass ends in which are placed various liquids to be tested for their rotatory effect. Or the object to be tested may be a doubly refracting crystal plate or a metallic reflector, rendering the plane-polarized light elliptically polarized; and the analyzer a **Babinet compensator** or similar device for identifying such light. In the simplest polariscopes the polarizer and the analyzer are reflecting plates of opaque glass set at the proper polarizing angle. Many modern polariscopes employ polarizing films, for example "Polaroids," instead of Nicols.

POLARISCOPE, CORNU. See **Cornu polariscope.**

POLARISTOR. The resistance formed when fine particles of some dielectric material suspended in a high dielectric fluid, such as oil, are subjected to a strong electrostatic field. The resistance between two points in the "liquid" is extremely non-linear, becoming much lower as the particles become polarized and align themselves with the field. For some materials strong fields may produce a solid "dry" mass.

POLARITY. (1) A line segment is said to exhibit polarity when its two ends are distinguishable. (2) By analogy with (1), a physical system has polarity when two points in the system have different characteristics. For example an electric **cell** has polarity, usually indicated by the plus and minus markings of its terminals. A coil has no polarity but a **transformer** does, since one of the two secondary terminals is positive at those times when a particular one of the two primary terminals is positive, and *vice versa*.

POLARITY OF PICTURE SIGNAL. See **picture signal, polarity of.**

POLARIZABILITY. The **dipole moment** produced by unit electric field acting on a system—usually a molecule. In the absence of permanent dipoles, the polarizability of a molecule is the sum of separate electronic polarizabilities (see **polarizability, electronic**) of its constituent atoms, with slight corrections due to the bond structure.

POLARIZABILITY CATASTROPHE. According to the standard theory of the **dielectric constant** of an assembly of dipoles, using the **Lorentz field** concept, at a certain temperature the dielectric constant would become infinite It has been proposed that at this temperature saturation effects enter, and the substance should become spontaneously polarized, or **ferroelectric.** This "$4\pi/3$ catastrophe," as it is sometimes called, is avoided by **Onsager's theory,** but the problem has not been completely settled. There is reason to believe that an assembly of dipoles might become **antiferroelectric** under their mutual interactions although this has never been observed in practice.

POLARIZABILITY, ELECTRONIC. That part of the **polarizability** of an atom which

arises from the displacement of the electrons relative to the nucleus. It is given by

$$\alpha = \frac{e^2}{m} \sum_j \frac{f_{ij}}{\omega_{ij}^2 - \omega^2}$$

where f_{ij} and ω_{ij} are the **oscillator strength** and frequency for the transition from the ground state i to the excited state j and ω is the frequency of the external measuring field.

POLARIZABILITY ELLIPSOID. A representation of the **electromagnetic theory** in anisotropic dielectric media may be given by the ellipsoid described by the equation:

$$\frac{x^2}{k_x} + \frac{y^2}{k_y} + \frac{z^2}{k_z} = 1$$

in which x, y, z are coordinate axes and k_x, k_y and k_z are the principal dielectric constants. If v_a represents the velocity of waves traveling perpendicular to the x-axis with their electric displacements parallel to the x-axis, then $v_a = c/\sqrt{k_x}$ (c = velocity of light in a vacuum) on the assumption that the magnetic permeability of the medium is that of empty space.

POLARIZABILITY, IONIC. That part of the **polarizability** in **ionic crystals** due to the relative displacement of ions of opposite sign when an electric field is applied, and giving rise to **infrared absorption.**

POLARIZABILITY, MOLECULAR. The constant of proportionality between the **electrical moment** of the **dipole** induced in a molecule and the **field intensity,** as in the relationship

$$m = \alpha F$$

in which m is the electrical moment of the induced dipole, α is the molecular polarizability, and F is the field intensity.

POLARIZABILITY, ORIENTATIONAL. The macroscopic **polarizability** associated with the orientation of permanent **dipole moments** by the field in a dielectric.

POLARIZATION. (1) The process of bringing about a partial separation of electrical charges of opposite sign in a body by the superposition of an external field. (2) A vector quantity representing the dipole moment per unit volume of a dielectric medium. In rationalized units, the **electric induction** in a **dielectric** is given by $\mathbf{D} = \epsilon\mathbf{E}$, which can be written

$$\mathbf{D} = \epsilon_r\epsilon_0\mathbf{E} = \epsilon_0 E + (\epsilon_r - 1)\epsilon_0\mathbf{E}$$

where ϵ_r is the relative permittivity or dielectric constant (κ) of the medium. The term

$$(\epsilon_r - 1)\epsilon_0\mathbf{E}$$

is the additional induction attributable to the matter of the dielectric, and is called the polarization of the dielectric. The coefficient $(\epsilon_r - 1)$ is the "electric susceptibility" of the dielectric, and is often written as χ_e. In unrationalized systems,

$$\chi_e = \frac{\epsilon_r - 1}{4\pi}.$$

(3) The process of confining the vibrations of the magnetic (or electric field) vector of light or other radiation to one plane (see **light, polarized**). (4) The formation of localized regions near the electrodes of an electric cell (see **cell, electric**) during electrolysis, of products which modify (usually adversely) the further flow of current through the cell.

POLARIZATION CHARGE. The net charge per unit volume, produced by a non-uniform **polarization,** is given by

$$\rho = -\nabla \cdot P$$

The polarization also produces an effective surface charge per unit area equal to the normal component of P. (See also **charge, bound.**)

POLARIZATION, CONCENTRATION. **Polarization** associated with a concentration gradient, which is due to the slowness of **diffusion** of ions in the vicinity.

POLARIZATION CURVE. The current-voltage relationship of an electrolytic system as plotted graphically, especially as it shows the progressive effect of the growth of a counter electromotive force due to **polarization** phenomena.

POLARIZATION, DIFFUSION. This is a negative expression, meaning that concentration polarization (see **polarization, concentration**) is caused by slowness of diffusion.

POLARIZATION, DIRECTION OF. For a **linearly-polarized wave,** the direction of the **electric vector.** This usage is common in ra-

dio and microwave discussions. The classical, and still standard, usage in optics is that the plane of polarization (see **plane of vibration**) is in the direction of the magnetic vector, and so is perpendicular to the electric vector. Because of these contradictory usages, confusion is best avoided if the direction of polarization is specifically stated in terms of the direction of the electric or of the magnetic vector.

POLARIZATION DIVERSITY. A form of **diversity** reception which utilizes the fact that, during fading conditions, the polarization of a received wave may change from horizontal to vertical or some intermediate angle. Two antennas, one horizontally-polarized, and the other vertically-polarized, are used at one point to feed two receivers whose output signals are added.

POLARIZATION, ELECTRIC. See **polarization (2).**

POLARIZATION, ELECTRIC MOMENT PER UNIT VOLUME (INDUCED DIPOLES). The induced electric moment per unit volume is given by the product of the net positive charge (= net negative charge), and the displacement of the individual positive charges from their accompanying negative charges.

POLARIZATION, ELECTROLYTIC. At a **reversible electrode** in a state of equilibrium, there is no net current. Application of an external emf destroys the equilibrium, and the electrode is polarized. This type of equilibrium disturbance is called electrolytic polarization.

POLARIZATION ELLIPSE (OF A FIELD VECTOR). The locus of positions for variable time of the terminus of an instantaneous **field vector** of one frequency at a point in space.

POLARIZATION ERRORS. Errors encountered in radio **direction-finders** due to the change in polarization of the received wave with changing atmospheric conditions.

POLARIZATION, INDUCED. An expression sometimes used for molar **polarization.** (See **polarization** and ***polarization electronic.***)

POLARIZATION, MAGNETIC (P_m). See both **induction, intrinsic,** and **magnetic moment density.**

POLARIZATION OF FLUORESCENCE. Fluorescence of solutions and of some other substances is partially polarized, but not to the extent of **polarization by scattering.**

POLARIZATION, PHI (Φ). The state of an electromagnetic wave in which the E-vector is tangential to the lines of latitude of reference. The usual frame of reference has the polar axis vertical, and the origin at or near the antenna. Under these conditions, a vertical dipole will radiate only theta (θ) polarization (see **polarization, theta**) and a horizontal loop will radiate only phi (ϕ) polarization.

POLARIZATION PHOTOMETER. In the main forms of **bench photometer,** the illuminations or luminous flux densities from the two sources to be compared are made equal by regulating the relative distances. In photometers of the polarization type, the same object is accomplished by introducing a pair of Nicol prisms into the beam from the brighter source and turning one of these polarizers until the beam is cut down to equality with that from the other source. The ratio in which the flux density has been reduced, and hence the luminous intensity ratio of the two sources, is readily calculated from **Malus' law,** and the polarizer circle may thus be calibrated to give the ratio directly.

POLARIZATION, PLANE OF. For a plane-polarized wave, the plane containing the direction of polarization (see **polarization, direction of**) and the **direction of propagation.**

POLARIZATION POTENTIAL. The total counterelectromotive force of an electrolytic (voltaic) cell, which increases as the process of **polarization** (4) within the cell proceeds, in the course of many electrolytic processes.

POLARIZATION RECEIVING FACTOR. The ratio of the power received by an antenna from a given plane-wave of arbitrary polarization to the power received by the same antenna from a plane wave of the same **power density** and **direction of propagation,** whose state of polarization has been adjusted for the maximum received power. The polarization receiving factor is equal to the square of the absolute value of the scalar product of the **polarization unit vector** of the given plane wave, with that of the radiation field of the antenna along the direction opposite to the direction of **propagation** of the plane wave.

POLARIZATION, SCATTERING. If a beam of light is passed through a medium containing small particles, the light scattered normal to the beam is plane-polarized. (See Robertson, *Introduction to Optics*, 4th Ed.) Light from a clear sky viewed normal to the direct rays from the sun will be plane-polarized.

POLARIZATION, SPONTANEOUS. The **polarization,** independent of applied field, of a **domain** of a **ferroelectric** crystal.

POLARIZATION, THETA (Θ). The state of an electromagnetic wave in which the E-vector is tangential to the meridian lines of some given spherical frame of reference. The usual frame of reference has the polar axis vertical, and the origin at or near the antenna Under these conditions, a vertical dipole will radiate only theta (Θ) polarization, and the horizontal loop will radiate only phi (ϕ) polarization. (See **polarization, phi.**)

POLARIZATION UNIT VECTOR (FOR A FIELD VECTOR). At a point, a complex field vector divided by its magnitude. For a field vector of one frequency at a point, the polarization unit vector completely describes the state of polarization, that is, the **axial ratio** and orientation of the **polarization ellipse** and the sense of rotation on the ellipse. A complex vector is one each of whose components is a complex number. The magnitude is the positive square root of the scalar product of the vector and its complex conjugate.

POLARIZATION, VACUUM. See **vacuum polarization.**

POLARIZED LIGHT. See **light, plane-polarized; light, elliptically-polarized;** and **light, circularly-polarized.**

POLARIZER. A device for producing polarized light, usually by selective transmission of polarized rays, such as a **Nicol prism,** a **Polaroid sheet,** or other apparatus.

POLARIZING ANGLE. See **light, plane-polarized; Brewster Law.**

POLARIZING PRISM. Any prism with the property of polarizing light such as the Cornu-Jellet, Glan, Nicol or Wollaston.

POLAROGRAM. The record, obtained on a **polarograph,** of a variation in current, or current-voltage relation. These records are applied in many phases of analytical and research work concerned with inorganic compounds, cations, anions, complex ions, certain catalysts, capillary active substances, many organic compounds, etc.

POLAROGRAPH. An instrument used to register a current-voltage relationship, particularly of the polarized microelectrodes used in **polarography.** The basic circuit of this instrument, as developed by Heyrovsky and Shikata, consists of a uniform slide wire, carrying a steady current which can be varied by changing the emf (number of batteries in its circuit) and by varying a series resistance. The electrolytic cell containing the microelectrode is in the circuit of the moveable slide-wire contact; this circuit also having a sensitive galvanometer, commonly a recording galvanometer, to measure or record the values of current flowing through the electrolytic cell as the potential across it is varied by moving the slide-wire contact. Modern machines produce these records automatically.

POLAROGRAPHY. The methods of measurement of potential difference-current relationships in solutions by means of a polarized microelectrode; and the interpretation of data or records so obtained in terms of the nature and behavior of many substances and systems. In an electrolytic cell having one electrode large in area, and the other electrode very small, the polarization of the latter approaches a maximum, and variations in the electromotive force of the cell are due almost entirely to changes in the potential of this electrode. Consequently, this microelectrode can function as an indicator electrode to measure changes in potential while current is flowing.

Many types of microelectrodes have been used successfully in polarographic work. The solid microelectrodes have been used extensively, both in stirred solutions, and by rotating the solid microelectrode in a stationary solution. Another important type is the dropping-mercury electrode, consisting of a slowly-growing drop of mercury issuing in small uniform drops from a glass capillary of small size (approximately 0.05 mm in diameter).

"POLAROID." The trade name of a polarizing sheet manufactured by the "Polaroid Corporation," U.S.A., and originally consisting of crystals of herapathite, a compound of iodine and quinine,

$$4C_{20}H_{24}N_2O_2 \cdot 3H_2SO_4 \cdot 2HI \cdot I_4 \cdot 6H_2O,$$

with their axes all parallel, and imbedded in nitrocellulose; but the material is now made in other ways. It produces almost perfectly plane-polarized light (see **light, plane-polarized**). Available in large sheets, relatively inexpensive compared to a **Nicol prism,** but not quite as perfect a polarizer as a Nicol prism.

POLE. (1) A non-essential **singularity** of an analytic function. Let $w = u + iv$ be a single-valued function of the complex variable, $z = x + iy$ and u,v be real single-valued functions of x and y. Then $z = z_0$ is a pole of order k, provided that $(z - z_0)^k w(z)$ is analytic and not zero at $z = z_0$. The number k is an integer, greater than unity, and is the order of the pole. Singular points of this kind are called non-essential because they may be effectively removed if $w(z)$ is multiplied by $(z - z_0)^k$. They are called poles because a three-dimensional plot of w,x,y shows that w becomes infinite at the singular point and thus looks like a pole of infinite length erected on the plane of $z = x + iy$. (See **Laurent series.**) (2) See **magnetic pole.** (3) The interaction of an axis of rotation or of symmetry with a surface, often spherical. (4) One electrode of an electric **cell.**

POLHODE. For a rotating rigid body subject to no external resultant **torque,** the line of intersection of the cone traced out by the angular velocity vector with the **momental ellipsoid.** (See also **herpolhode.**)

POLISHING (OPTICAL). After the surface of a lens or mirror has been ground (see **lap**) as fine as possible, it is polished. Optical polishing is an art rather than a science, and many techniques are in use. The abrasive used in polishing is most commonly an iron oxide or cerium oxide, although other substances are occasionally used for special purposes. The polishing tool may be a pitch-covered iron tool or an iron tool covered with pitch-impregnated felt. Almost as many sorts of pitch are used as there are optical shops. Amateur lens polishers frequently use HCF, that is, honey-comb foundation, made from beeswax. Interference fringes (**Newton rings**) between a true optical flat and a flat polished with HCF, commonly show more ragged edges to the lines than are seen on pitch-polished surfaces.

POLONIUM. Radioactive element. Symbol Po. Atomic number 84.

POLYCHROMIC (POLYCHROMATIC). Having two or more colors.

POLYDISPERSE SYSTEM. A **colloidal system** that consists of particles of different sizes. In centrifuging, the **sedimentation constant** has different values for a polydisperse system.

POLYGON. A plane figure with n vertices and n sides, also called an n-gon. Depending on the value of n, the following names are used: 3, triangle, 4, quadrilateral; 5, pentagon; 6, hexagon; 7, heptagon; 8, octagon; 9, nonagon; 10, decagon, etc. If all sides and angles are equal, the polygon is **regular.** Let A be the angle between two sides, B the angle between lines connecting the center of an inscribed or circumscribed circle to two adjacent vertices, a the length of a side, R the radius of a circumscribed circle, r the radius of an inscribed circle, and S the area of a regular polygon with n sides, then

$$A = (n - 2)\pi/n \text{ radians}; \; B = 2\pi/n \text{ radians}$$

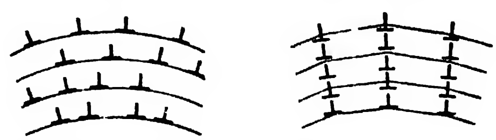
$$a = 2R \sin B/2; \; r = (a/2) \cot B/2$$

$$R = (a/2) \csc B/2; \; S = (na^2/4) \cot B/2$$

POLYGON, DIAGONAL OF. A line joining two non-adjacent vertices of a polygon.

POLYGON, SPHERICAL. A part of a sphere bounded by arcs of great circles.

POLYGONIZATION. When plastically bent crystals are **annealed,** the **edge dislocations**



introduced by the **cold-working** tend to line themselves vertically above each other into **grain boundaries** between polygonal domains. (See **dislocations, forces between.**)

POLYHEDRON. A solid with faces formed from plane **polygons.** The intersections of faces are **edges** and the points where three or more edges meet are **vertices.** If the faces are congruent regular polygons and the polyhedral angles are congruent, the polyhedron is **regular.** There are only five regular polyhedra, called the Platonic solids. Their

names and the nature of their faces are: tetrahedron, 4 equilateral triangles; hexahedron or cube, 6 squares; octahedron, 8 equilateral triangles; dodecahedron, 12 pentagons; icosahedron, 20 equilateral triangles.

POLYMORPH. A substance that exhibits two or more crystalline forms.

POLYMORPHIC. Existing in two or more crystalline forms.

POLYMORPHISM. A phenomenon in which a substance exhibits different forms. Dimorphic substances appear in two crystal forms, whereas trimorphic exist in three, as sulfur, carbon, tin, silver iodide, and calcium carbonate. Polymorphism is restricted to the solid state. Polymorphs yield identical solutions and vapors (if vaporizable). The relation between them has been termed "physical isomerism" and the polymorphs have been termed "physical isomers."

POLYNOMIAL. A **rational integral function** sometimes also called a **multinomial,** in n variables of the form

$$c_1x_1^{\alpha_1}x_2^{\beta_1}\cdots x_n^{\nu_1}+c_2x_1^{\alpha_2}x_2^{\beta_2}\cdots x_n^{\nu_2}+\cdots + c_kx_1^{\alpha_k}x_2^{\beta_k}\cdots x_n^{\nu_k}.$$

For any term in this expression c_i is the coefficient, α_i is the degree with respect to x_1, β_i with respect to x_2, etc., and the total degree of that term is $\alpha_i+\beta_i+\cdots\nu_i$. The highest degree in x_i of any term whose coefficient is not zero is the degree of the polynomial in x_i, and the highest total degree of any term with non-vanishing coefficient is the degree of the polynomial. The coefficients, c_i, which are constants, may be real or complex.

If the terms of a polynomial all have the same degree, the polynomial is homogeneous. The expressions quantic and form are also used. If they have two, three, four, etc., variables they are binary, ternary, quaternary, n-ary forms; if their degree is 1, 2, 3, etc., they are linear, quadratic, cubic, etc., forms.

The commonest case is the nth degree polynomial in one variable which may be written as

$$a_0x^n+a_1x^{n-1}+\cdots+a_{n-1}x+a_n;$$

(see **equation, polynomial**).

Polynomials frequently occur as the solution of a differential equation. (See **Hermite, Jacobi, Laguerre, Legendre, Tschebyscheff polynomials.**)

POLYPHASE RECTIFIER. See **rectifier.**

POLYPHASE WATTHOURMETER. See **watthourmeter, polyphase.**

POLYPHASE WATTMETER. See **wattmeter, polyphase.**

POLYTROPIC PROCESSES. The expansion or compression of a constant weight of gas may assume a variety of forms, depending on the extent to which heat is added to or rejected from the gas during the process, and also on the work done. There are, theoretically, an infinite number of ways possible in which a gas may expand from an initial pressure p_1, and volume v_1 to a final volume v_2. All these expansions may be grouped generically as polytropic expansions, and all could be represented graphically on the PV plane by the family of curves $pv^n = C$. They are all, in theory, perfectly reversible. n may have any positive value, 0 to ∞, and having been selected numerically it defines the type of expansion From the infinite number of possible polytropic expansions, it is worth while to isolate four which deserve special attention. When one of the four physical characteristics, to wit, **pressure, temperature, entropy,** or volume, remains constant, expansions of more than ordinary interest are denoted, since they are frequently employed in a practical way, in situations which can be subjected to thermodynamic analysis. The value of the exponent n of the polytropic family for each of these is:

Isobaric	$n = 0,$	
Isothermal	$n = 1,$	
Isentropic	$n = \gamma$	(γ = ratio of specific heat at constant pressure to that at constant volume)
Isometric	$n = \infty.$	

These thermodynamic processes, as they occur in useful machines, are not often of the exact polytropic form desired. For example, an isentropic process which is exemplified, at least theoretically, by expansion of the burned gases after the explosive combustion in the gasoline engine, is modified slightly by the interchange of heat between gases and cylinder wall, whereas a true isentropic has no heat either added or rejected in this way. The

particular polytropic curve which would suit these conditions of expansion would depart somewhat from the adiabatic form.

During a polytropic process conditions of the working medium are constantly varying, and analysis may be aimed at determining one of the following: the work done, the heat added, the variation of temperature, and the change of entropy. Some information may be obtained merely by comparing the value of the exponent n with certain other data. For example, if n lies between 0 and 1, the temperature rises during an expansion and falls during a compression; when n is greater than 1, the temperature falls during expansion and rises during compression. Also, when n is less than γ, heat must be added to obtain an expansion, whereas when it is greater than γ, heat must be expelled. From the above it will be noted that there is a certain range of polytropic expansion in which, although heat is added, the temperature falls. This may seem to some to be paradoxical, but it is readily explained. During these expansions work is being done by the gas at a rate greater than that at which heat is being added, with the result that the deficiency must be made up from within the gas. The only way that this may be accomplished is for the gas to cool and give up some of its internal energy.

The equations for work done and for heat added in the case of the general polytropic expansions are:

$$W = \frac{p_1v_1 - p_2v_2}{n - 1}.$$

$$Q = (p_1v_1 - p_2v_2)\left(\frac{1}{n-1} - \frac{1}{\gamma - 1}\right).$$

Both of these are expressed in work units. Sometimes a substitution of a definite value of n in one or the other of these equations leads to an indeterminate; for example, with the isothermal,

$$W = \frac{p_1v_1 - p_2v_2}{1 - 1}.$$

But since the equation of the isothermal for an ideal gas is

$$pv = C,$$

$$p_1v_1 = p_2v_2,$$

and the work equation becomes indeterminate:

$$W = \frac{0}{0}.$$

By approaching the isothermal from a different angle, however, the equation

$$W = pv \log_e \frac{v_2}{v_1}$$

may be deduced for work done.

PONDERATOR. A term suggested by W. W. Hansen for a device used to produce high-energy particles, when the speed of the particles becomes so great, approaching that of light, that an increase of energy results in an appreciable increase in mass.

POOL TUBE. A **gas-discharge tube** having a cold cathode consisting of a pool of mercury. (See **ignitron; excitron.**)

POROSIMETER. An instrument used to determine the porosity of solids to fluids, both liquids and gases.

POROSITY. (1) The property of containing pores, which are minute channels or open spaces in a solid. (2) The proportion of the total volume occupied by such pores.

PORRO PRISM. See **prism, Porro.**

POSITION. A concept which implies the possibility of locating a particle in public space with respect to a reference system. (See **primary inertial system.**)

POSITION FACTOR. See **Coddington shape and position factors.**

POSITIONAL NOTATION. One of the schemes for representing real numbers, characterized by the arrangement in sequence of digits (symbols for integers) with the understanding that the successive digits are to be interpreted as the coefficients of successive integral powers of a number called the radix or base of the notation The representation of a real number by the notation

$$A_nA_{n-1} \cdots A_2A_1A_0.A_{-1}A_{-2} \cdots A_{-m},$$

which is an abbreviation for the sum

$$\sum_{i=-m}^{n} A_ir^i$$

where the . is called the radix point, the A_i are integers ($0 \leqq |A_i| \leqq r$) called digits, and r is an integer greater than one called the radix (or base). The signs of all of the A_i are the same as the sign of the number repre-

sented. In the decimal number system, the radix is ten and the radix point is called the decimal point. In the binary number system, the radix is two and the radix point is called the binary point. For some purposes the system of notation has been broadened to include the case in which the radix assumes more than one value in a single number system. In this case the notation

$$A_nA_{n-1}\cdots A_2A_1A_0.A_{-1}A_{-2}\cdots A_{-m},$$

is an abbreviation for the sum

$$\left(\sum_{i=1}^{n} A_i\prod_{j=1}^{i} r_j\right) + A_0 + \left(\sum_{i=-m}^{-1} A_i\prod_{j=i}^{-1}\frac{1}{r_j}\right).$$

Several such systems have been used. The biquinary system uses a radix which is alternately two and five for successive values of j. The quinary vicenary system uses a radix which is alternately five and twenty for successive values of j. For the names of various number systems, as characterized by their radix, see **radix.**

POSITIVE BRANCH. See **Fortrat parabola.**

POSITIVE COLUMN. Another name for the **plasma.**

POSITIVE COUPLING. See **coupling, positive.**

POSITIVE CRYSTAL. A uniaxial crystal (see **crystal, uniaxial**) in which the velocity of the ordinary ray is greater than the velocity of the extraordinary ray. Quartz is a positive crystal.

POSITIVE GRID OSCILLATOR. See **Barkhausen-Kurz oscillator.**

POSITIVE ION VACANCY. A site in the **lattice** of an **ionic crystal** from which a positive ion is absent. Such a vacancy has an effective negative charge, since returning the missing ion must make the lattice neutral.

POSITIVE LENS SYSTEM. Another name for a **convergent lens system.**

POSITIVE MODULATION. See **modulation, positive.**

POSITIVE NUCLEUS. The nucleus of an atom, which always carries a positive charge, of magnitude depending upon the particular atomic species. (See **atomic structure.**)

POSITIVE PICTURE PHASE. See **modulation, positive.**

POSITIVE RAYS. A stream of positively charged atoms or molecules, produced by a properly chosen combination of ionizing agents, accelerating fields and limiting apertures.

POSITIVE TRANSMISSION. See **modulation, positive.**

POSITIVE TUBE. The term sometimes given a **thyratron** with a positive-grid characteristic (i.e., a positive grid-voltage is required to initiate the discharge).

POSITRON. A positive electron. Positrons are formed in **β-decay** of many radionuclides, in **pair production,** and in other processes.

POSITRON EMISSION, CONDITIONS FOR. If $M(A)$ is the isotopic (atomic) weight of the parent element A and $M(B)$ that of the product B, the condition that positron emission be energetically possible is that

$$M(A) - M(B) \geq 2m_0 \quad (2m_0 \doteq 1.02 \text{ Mev})$$

where m_0 is the **rest mass** of an electron.

POSITRON FORMATION THEORY. It is supposed that prior to its emission (in β-decay) a **positron** is created in the nucleus by a process such as

proton → neutron + positron + antineutrino.

Positrons may also be formed in the **pair-production** process, in which a γ-ray of sufficient energy (at least 1.02 mev) is transformed into a positron-electron pair.

POSITRON THEORY. Theory of the interaction of positrons with an electromagnetic field which is a consequence of the many-particle **Dirac electron theory.** A hole in the distribution of negative energy electrons which is a feature of this theory behaves like a particle of positive charge, and although originally identified with the **proton** it was soon recognized as a particle with mass equal to that of the electron. Transition of an electron from a positive energy state to a negative energy state is thus interpreted as the annihilation of an electron-positron pair. It is possible to set up the theory in a form which is completely symmetrical with respect to elec-

trons and positrons. (See **Feynman diagram; motion backwards in time; quantum electrodynamics.**)

POSITRONIUM. The system of one electron and one positron in a bound state. In the 1s state it may exist as **parapositronium** with a mean life of 1.25×10^{-10} sec or as **orthopositronium** with a mean life of 1.4×10^{-7} sec. The latter has a value of 203350 ± 50 megacycles above that of the former.

POST-ACCELERATION (IN AN ELECTRON-BEAM TUBE). Acceleration of the beam electrons after deflection.

POST, CAPACITIVE. A **waveguide** tuning or matching device which consists of a metal post or screw extending completely across the waveguide at right angles to the E-field In this position the post adds capacitive **susceptance** in parallel with the guide

POST-EMPHASIS. See **de-emphasis.**

POST-EQUALIZATION. See **de-emphasis.**

POST-FIRING. Post-firing refers to the interval during the gating or output alternation following firing. The term is used as an adjective to describe phenomena occurring during this interval.

POST, INDUCTIVE. A **waveguide** tuning or matching device which consists of a metal post or screw extending completely across the waveguide parallel to the E-field In this position the post adds inductive **susceptance** in parallel with the guide.

POST OFFICE BOX. A Wheatstone bridge (see **bridge, Wheatstone**) in which resistance is adjusted by shorting resistance elements with heavy plugs.

POTASSIUM. Metallic element. Symbol K. Atomic number 19.

POTENTIAL. Among its many meanings and connotations, this term is used commonly in science as an adjective with the meaning of available, rather than in action or use, as potential energy (energy of position or state) as opposed to kinetic energy. The term potential is also used as a substantive, and in this sense designates the name of a number of different quantities used in physics, such as electric potential (see **potential, electric**), magnetic potential (see **potential, magnetic**), nuclear potential (see **potential, nuclear**) and gravitational or mass potential, the latter being defined at any point as the energy necessary to carry a unit mass from that point to a region of space infinitely removed from all matter. Its value is the integral of $G(dm/r)$, where G is the **gravitational constant,** dm is any mass element, and r is the distance from the point in question; the integration being extended throughout all existing matter. Electric potential and magnetic potential at a point are defined as the energy necessary to carry unit charge, or unit pole, respectively, from infinity to that point. The "Newtonian potential function" is a mathematical expression occurring as a factor in all these potentials. (See **Laplace equation.**)

A characteristic of the mass potential, the electric potential, and the magnetic potential, is that in each case the first derivative of the potential with respect to any direction, as x, at any point in space, is equal in magnitude to the component of the field intensity in that direction at the point in question.

The foregoing potentials all involve inverse-square forces; if the field obeys the inverse-first-power law, the potential involves the logarithm of the distance, and is called the "logarithmic potential"

By analogy, we have also a so-called **"thermodynamic potential,"** which, in reference to a substance in any state, represents the energy which has been required to bring unit mass of the substance to the state in question from some arbitrarily defined, initial state.

In physics, a "potential field" is a vector field derivable from a scalar potential, as $\mathbf{E} = \nabla \phi$. Any vector $\mathbf{V}$ such that $\nabla \times \mathbf{V}$ 0 can be so expressed. Conversely, any vector $\mathbf{B}$ such that $\nabla \cdot \mathbf{B} = 0$, can be expressed as $\mathbf{B} = \nabla \times \mathbf{A}$, as in **magnetostatic field.** $\mathbf{A}$ is called a **vector potential.**

POTENTIAL, ADVANCED. See **advanced potential.**

POTENTIAL, APPEARANCE. See **appearance potential.**

POTENTIAL, ASYMMETRY. See **asymmetry, potential.**

POTENTIAL BARRIER. A region including a maximum of **potential** which prevents a low energy particle on one side of the region

from passing to the other side. The electrical repulsion of a nucleus for a positively-charged particle, e.g., an α-particle, computed by the **law of Coulomb,** leads to such a barrier surrounding a **nucleus.** Although by classical physics a particle must possess an energy exceeding the height of the potential barrier to pass this barrier, the wave mechanical interpretation shows that there is a definite possibility that a particle with less energy may do so. (See **penetration probability.**)

POTENTIAL, COEFFICIENTS OF. Consider a system of n conductors bearing charges $q_1 \cdots q_n$. Let the potentials of the conductors be $V_1 \cdots V_n$. The potentials are linear functions of the charges:

$$V_1 = p_{11}q_1 + p_{12}q_2 + \cdots + p_{1n}q_n$$
$$V_2 = p_{21}q_1 + p_{22}q_2 + \cdots + p_{2n}q_n$$
$$V_n = p_{n1}q_1 + p_{n2}q_2 + \cdots + p_{nn}q_n.$$

The coefficients p_{ij} are called potential coefficients. Their matrix is symmetric ($p_{ij} = p_{ji}$). The inverse matrix gives the q's as functions of the V's:

$$q_1 = c_{11}V_1 + \cdots + c_{1n}V_n$$
$$q_n = c_{n1}V_1 + \cdots + c_{nn}V_n.$$

The inverse elements $c_{ij} = c_{ji}$ are the coefficients of mutual electrostatic induction.

POTENTIAL, CONTACT. A difference of **electrical potential** existing between two substances in direct contact. All metals, electrolytic solutions, and other substances containing "free" ions or electrons, exhibit a difference of potential on direct contact

POTENTIAL, CRITICAL. See **critical potential.**

POTENTIAL DIAGRAM. A curve showing the **potential** or the **potential energy** of a particle or system of particles as a function of the coordinate(s). A plot of $U(r)$ as a function of r when the function is defined by the **Morse equation** is an example, as are the figures shown in the entry on **potential, nuclear.**

POTENTIAL DIFFERENCE. Consider a **direct-current** electric **circuit** divided into two parts: (1) a box containing sources of emf and (2) a box containing no sources. The potential difference across the common terminals of these boxes is

$$V = IR_L = \mathcal{E} - IR_g$$

where I is the current, R_L the resistance of the "load" box, $\mathcal{E}$ the emf of the "generator" box, and R_g the resistance of the "generator" (See also **electrostatics; potential.**)

POTENTIAL DIFFERENCE, CONTACT. See **potential, contact.**

POTENTIAL, DIFFUSION. The difference of potential at the boundary of an electrical **"double layer."** This is also called the **liquid junction potential.**

POTENTIAL, DISCHARGE. A characteristic value of the **electrode potential,** observed in the electrode potential-current relationship determined for an electrode in contact with an ionic solution The distinguishing feature of this value is that it marks a point of inflection, at which the current increases very rapidly with small increases in electrode potential. This high current value is marked by discharge of ions upon the electrode

POTENTIAL DIVIDER. See **voltage divider.**

POTENTIAL DROP. The potential drop in a branch of an electric **network** is $\Delta V = IR$, the product of current and resistance. This generalizes to IZ (Z being impedance) in the case of **alternating current.**

POTENTIAL DROP, LAW OF. See **electric circuits; electric currents.**

POTENTIAL, ELECTRIC. If a charge of **electricity** is moved from one region of space to another, it encounters, in general, electric forces which either help or hinder the transfer and which therefore add to or subtract from the **potential energy** of the charge. Suppose that a positive unit charge has been brought into the region A from a region so remotely beyond the borders of the material universe that no electric forces exist there. In general, a certain amount of work, V_A, has been done against the electric forces encountered on the way in; consequently V_A may be regarded as the potential energy which the unit charge has acquired in the process. This work per unit charge, V_A, is called the absolute electric potential of the region A. It is a scalar quantity, and may be either positive or negative; for example if A is in the vicinity of a large negative charge, the unit positive charge has been attracted and has done work, or lost po-

tential energy, during its journey, and V_A is therefore negative. If a second region B is at a potential V_B, less than V_A, the unit charge would lose potential energy in moving from A to B, in the amount $V_A - V_B$. Thus, in an electrolytic cell, a positive ion migrates from the high-potential to the low-potential electrode, and does work in heating the solution. Negative charges tend to migrate from lower- to higher-potential regions; this is illustrated by the electrons in a wire.

The absolute zero of potential is of course that at an infinite distance from the universe; but for practical purposes an arbitrary zero is used, commonly that of the earth's surface (which is by no means constant); or that of some other large **conductor,** such as the metallic base or case of the apparatus being used. The ordinary unit of electric potential is the **volt.** (See **electromotive force** and **electrostatics, laws of.**)

POTENTIAL ENERGY. See **energy, potential.**

POTENTIAL ENERGY, NUCLEAR. The average total potential energy of all of the nucleons in a nucleus due to the specifically nuclear forces between them, but excluding the electrostatic potential energy.

POTENTIAL FLOW. Flow in which the (vector) flow velocity is the **gradient** of a scalar function of position, the velocity potential. The flow of an inviscid and incompressible fluid set in motion by pressures on the boundaries or by external fields of force derivable from a potential is irrotational at all subsequent times and so has a velocity potential.

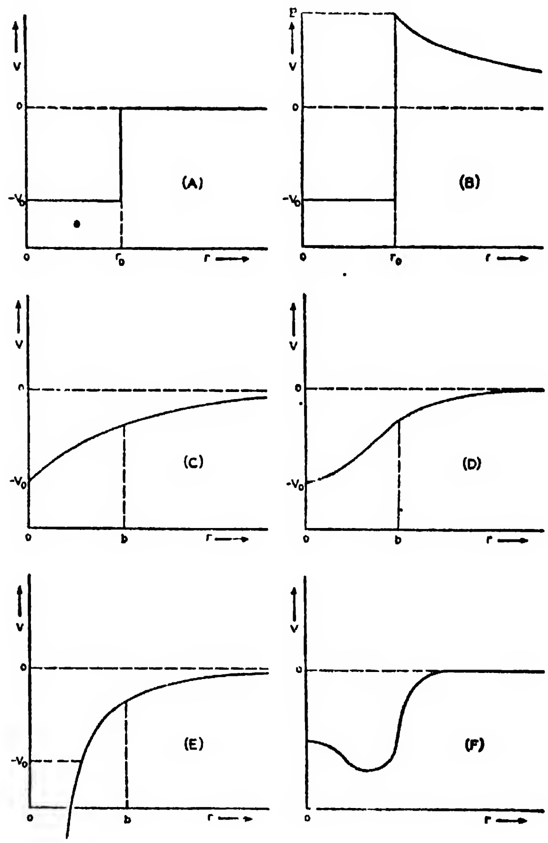
POTENTIAL FUNCTION. A scalar function satisfying the **Laplace equation:**

$$\nabla^2\phi = 0.$$

POTENTIAL, IONIZATION. See discussion of **critical potential.**

POTENTIAL, LIQUID JUNCTION. See **liquid junction potential.**

POTENTIAL, NUCLEAR. The potential energy V of a nuclear particle as a function of its position in the field of a nucleus or of another nuclear particle. A central potential is one that is spherically symmetric; that is, V is a function only of the distance r from the center of the field, thus being the same in all directions, and is representable by a curve as in Figs. (A)–(F). A potential well is the region about a minimum in the potential; it results from attractive forces. A potential barrier is the region about a maximum in the potential; it results from repulsive forces, either alone or in combination with attractive forces. Some central potentials commonly used as approximations to nuclear



potentials are illustrated in the figures. (A) shows a square well potential, which has a constant negative value $-V_0$ for $r \leqq r_0$ and zero value for $r \geqq r_0$. When this curve represents the potential between two nucleons, r_0 is called the range of nuclear forces; when it represents the potential of a nucleus, for a nucleon, r_0 is called the **nuclear radius.** (B) shows a square well potential for $r \leqq r_0$ with a Coulomb potential resulting from repulsive electrostatic forces, for $r > r_0$. The resulting barrier is called a Coulomb barrier, and the maximum energy B is called the barrier height. Such a potential approximates that of a positively charged particle in the field of

a nucleus, and is often used in the theory of α-disintegration and nuclear reactions. (C) shows an exponential well, $V = V_0 e^{-r/b}$, (D) shows a Gaussian well, $V = V_0 e^{-r/b^2}$. (E) shows a Yukawa potential. $V = -(V_0/r)e^{-r/b}$ used in the **meson theory of nuclear forces** for the interaction between two nucleons. (F) shows a wine-bottle potential, characterized by a low central elevation. If a high central elevation is present, the resulting barrier is called a central barrier.

POTENTIAL OF A FIELD OF FORCE. **Potential energy** per unit mass for a gravitational field of force or per unit charge for an electrostatic field of force.

POTENTIAL, OXIDATION. See **oxidation potential.**

POTENTIAL, REDUCTION. See **reduction potential.**

POTENTIAL, RESONANCE. See discussion of **critical potential.**

POTENTIAL SCATTERING. See **scattering, potential.**

POTENTIAL, SPARKING. The difference in electrical **potential** necessary to cause an electrical spark to pass between two given points in a given medium under a given temperature and other conditions.

POTENTIAL, STANDARD. The potential of an **electrode** composed of a substance in its **standard state,** in equilibrium with ions, which are all in their standard states. (See **hydrogen scale.**)

POTENTIAL, STICKING. The limiting value of screen-to-cathode potential on a **cathode-ray tube** with a non-conducting backing for the **phosphor.** The fact that this potential cannot be exceeded regardless of the accelerating voltage limits the brightness of the **spot** which can be achieved. This limiting action normally occurs between 4 and 10 kilovolts for the plain phosphor, when the number of secondary-emission electrons from the screen falls below the number of beam electrons.

POTENTIAL, STOPPING. That potential required to bring an emitted electron to rest—thus a measure of the initial velocity or the energy of the electron. The magnitude of this quantity when the electrons are emitted from a surface by the **photoelectric effect** of light, is equal to $(h\nu - h\nu_0)/e$ where h is the Planck constant, ν is the frequency, and e is the charge of an electron (in consistent units).

POTENTIAL, STRIKING. (1) That potential required to initiate an arc. (2) That starter-anode potential for a cold-cathode gas **triode** which will initiate anode current flow.

POTENTIAL TEMPERATURE. The temperature that a compressible fluid would attain if it were compressed (or expanded) **adiabatically** from its existing state to a standard pressure, commonly 1000 millibar = 10^6 dyne cm^{-2}. Potential temperature is really a measure of **entropy,** and it is used in meteorology to assess the convectional stability of air masses. Temperature and pressure of a parcel at its existing level and its potential temperature are related as indicated by the equation,

$$\theta = T\left(\frac{1000}{p}\right)^{0.288}$$

where θ is the potential temperature, T is the actual temperature, and p is the actual pressure.

POTENTIAL TEMPERATURE, EQUIVALENT. The temperature that a given sample of air would have if it were brought adiabatically to the top of the atmosphere (i.e., to zero pressure) so that along its route all the water vapor present were condensed and precipitated, the latent heat of condensation being given to the sample, and then the remaining dry air compressed adiabatically to a pressure of 1000 millibars.

POTENTIAL, VECTOR. See **vector potential.**

POTENTIALS, WAVE. See **wave potentials.**

POTENTIAL WELL. See **potential, nuclear.**

POTENTIOMETER. (1) An instrument used for the measurement or comparison of small potential differences or electromotive forces, based upon the "law of potential drop" (see **electric circuits**). One of the simplest potentiometer circuits is shown in the accompanying diagram. Current from a battery B is sent

through a resistance MN and is adjustable by means of a rheostat A. From one extremity

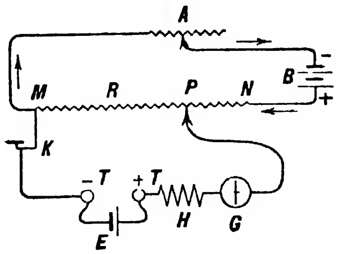


Diagram of potentiometer circuit

M of this resistance is taken off a branch circuit containing the potentiometer terminals $+T$, $-T$, between which E, one of the electromotive forces to be compared, is connected. This circuit rejoins the main circuit at a point P which is adjustable so that the partial resistance MP or R can be varied, while MN as a whole remains constant. The + and − leads from E must be connected as shown, and the electromotive force of B must exceed E. The position of P is now adjusted until the galvanometer G shows no current, indicating that the potential drop from P to M just balances the electromotive force E. If two different electromotive forces E_1, E_2, are thus connected and balanced in succession, and if the corresponding values of the resistance MP are R_1, R_2, then since the current through MN is unaltered, the law of potential drop gives

$$\frac{E_1}{E_2} = \frac{R_1}{R_2}.$$

In particular, one of the electromotive forces may be a **standard cell** of accurately known voltage; the other is thereby determined. In such case the standard cell should be safeguarded by a high resistance H, which is gradually reduced as the zero-current adjustment is approached; and the key K should be closed only for an instant. In some potentiometers the whole equipment, including galvanometer and standard cell, is contained in one compact case. (2) The term potentiometer is also used to denote a three-terminal voltage-dividing network such as is used in volume controls for radio receivers, etc. Confusion may be avoided if the term **voltage-divider** is used for this purpose.

POTENTIOMETER, BROOKS DEFLECTION. A **potentiometer** designed to be set at an approximate null, the error voltage then being directly readable from the galvanometer.

POTENTIOMETER, CAMPBELL-LARSEN. A modification of the Larsen potentiometer (see **potentiometer, Larsen**) that can be made direct-reading in volts for any selected frequency.

POTENTIOMETER, COORDINATE. An a-c **potentiometer** in which the balancing voltage is obtained by varying the magnitudes of two alternating voltages which are in quadrature with each other.

POTENTIOMETER, DIESSELHORST DIFFERENCE. A **potentiometer** arrangement wherein the supply current is fed to a "resistance circle" via a rotatable, diametral slider. An adjustable voltage is thus provided between two fixed points on opposite sides of the circle. The supply current is divided onto the two paths; the difference of potential drops taken from these two paths is the output voltage of the **divider.**

POTENTIOMETER, DIRECT-READING. A **potentiometer** with the slide-wire calibrated in volts. By setting the dial at the known voltage of the **standard cell,** and adjusting the supply current for balance, the slide-wire position for balance of an unknown emf gives a direct reading of the unknown voltage

POTENTIOMETER, DRYSDALE. An a-c polar potentiometer (see **potentiometer, polar**) in which the constant operating current is measured by an electrodynamic milliammeter. The **voltage-divider** is calibrated by using a direct current supply and balancing against a standard cell. Substitution of an alternating current of the same magnitude yields the desired alternating voltage at the divider. A **phase-shifter** must be incorporated in the a-c supply to adjust the phase of the balancing voltage to that of the unknown

POTENTIOMETER, GALL. A coordinate potentiometer (see **potentiometer, coordinate**) comprising two similar potentiometers supplied by quadrature currents.

POTENTIOMETER, LARSEN. A coordinate potentiometer (see **potentiometer, coordinate**) utilizing **resistance** and **mutual inductance** in the **phase splitter.** The adjustments are frequency-dependent. The frequency must be known accurately, and only

at one frequency can it be made direct-reading in volts.

POTENTIOMETER, LINDECK. Most **potentiometers** balance the unknown emf against a variable emf derived from a variable resistance carrying constant current. The Lindeck arrangement uses a fixed resistance, whose current is varied to achieve balance.

POTENTIOMETER, MAGNETIC. A **solenoid** wound on a flexible non-magnetic core, connected to a ballistic galvanometer (see **galvanometer, ballistic**). The difference of magnetic potential between two points can be measured by moving one end of the solenoid from the first point to the second, with the other end of the solenoid stationary.

POTENTIOMETER, PEDERSEN. A coordinate potentiometer (see **potentiometer, coordinate**) for comparing two alternating voltages. It utilizes a fixed, frequency-insensitive, **phase-splitter** for obtaining the requisite quadrature components.

POTENTIOMETER, POLAR. An a-c **potentiometer** in which the unknown voltage is balanced by means of a single voltage which is variable in both magnitude and phase. (Cf. **potentiometer, coordinate.**)

POTENTIOMETER, RUBICON MICROVOLT. A commercial-design potentiometer based on the Brooks standard-cell comparator (See **potentiometer, standard-cell comparator.**)

POTENTIOMETER, SIN. A potentiometer which, when supplied with a suitable d-c supply voltage, will have an output voltage proportional to the sine of the shaft position angle. Used as a **resolver** in computer and radar systems.

POTENTIOMETER, STANDARD-CELL COMPARATOR (BROOKS). A combination incorporating both constant current, variable-resistance adjustment and constant resistance, variable current adjustment. It was specifically designed for comparing **standard cells** to 1 microvolt.

POTENTIOMETER, TINSLEY VERNIER. A **potentiometer** in which part of the current-carrying circuit consists of a series of n identical coils, each of resistance r. Another set of m coils, each of resistance $2r/m$, are arranged so that they may be connected in parallel with two of the coils of resistance r. A contact moving over the contacts between adjacent coils of the second set allows adjustment of the point of connection to an accuracy r/m.

POTENTIOMETER, WENNER DIFFERENCE. A divided-circuit type of **potentiometer** wherein the supply current is in a fixed resistance "circle," and there is a fixed resistance diametral shunt which can be "rotated" around the circle.

POTENTIOMETER, WHITE COMBINATION. A cascaded arrangement of a high-range **potentiometer** and a low-range potentiometer The high range is adjustable in steps of, say, 100 microvolts. The low range potentiometer then measures the residual unbalance voltage, which cannot exceed 100 microvolts.

POTENTIOMETER, WULF. A **potentiometer** in which two identical sets of coils are used, with a switching arrangement which increases the resistance in one set and simultaneously decreases the resistance in the other set by the same amount. The two sets are in series, one being included in the galvanometer circuit and the other only in the battery circuit. The total resistance is thus kept constant while the resistance in the galvanometer circuit is varied.

POUND. A unit of mass in the English system of weights and measures. Unless specified otherwise, it is understood to be the avoirdupois pound of 453.59 grams, rather than the troy pound of 373.24 grams. It is also used as a unit of force, in which case it is the weight of one pound at a location where g = 32 174 ft/sec^2 (cf. **poundal**). The equivalents are as follows:

1 pound avoirdupois	= 16 av. ounces
1 pound avoirdupois	= 7000 grains
1 pound avoirdupois	= 0.45359 kilogram
1 pound avoirdupois	= 453.59 grams
1 pound troy	= 373.24 grams
1 pound troy	= 12 ounces troy
1 pound troy	= 5760 grains

POUNDAL. A unit of force in the f lbm s system, being the force which imparts an acceleration of 1 ft/sec^2 to a mass of one pound. Equal to 1 lbf/32.174.

POWDER METHOD OF ANALYSIS. A method for the **x-ray analysis** of **crystals.** A beam of x-rays is directed on the finely-powdered crystalline material, by which it is diffracted. Many minute crystals in the powder are oriented in the correct direction for the **Bragg equation** to be applied to the determination. The diffracted x-rays are allowed to impinge on a film strip which surrounds the powder; characteristic ring patterns are then obtained. The x-ray photograph made in the process is characteristic of each crystalline material, and so can be used in identification.

POWDER PATTERN. An improvement of the elementary scheme of using iron filings to portray magnetic fields. The use of very fine powders or colloidal particles of magnetic material allows the graphic demonstration of magnetic **domains** in a single crystal of ferromagnetic material.

POWELL BANDS. **Talbot bands** produced when the glass plate is introduced into a hollow prism containing a liquid.

POWER. (1) The time rate of doing work. The defining equation for power is $P = dW/dt$, where W is the work done and t is the time.

It may be expressed in units of work per unit time (e.g., foot-pounds per minute or ergs per second) or more arbitrarily, as in horsepower or watts. One horsepower is 33,000 foot-lbs per minute. One watt is 10^7 ergs (or 1 joule) per second.

(2) A power a^m with a positive integral exponent m is the repeated product of m factors each equal to a. $a^m = a \cdot a \cdot \cdots a$ (m factors). The number a is called the base, m is called the exponent and a^m is called the power. A power with zero exponent is defined to be unity provided the base is non-zero. A power with a positive fractional exponent m/n where m and n are positive integers is defined as the principal nth root of the mth power of a. A power with a negative exponent is defined as the reciprocal of the corresponding power with the positive exponent. The fundamental laws of exponents are expressed by the formulae:

$$a^m \cdot a^n = a^{m+n}$$

$$a^m \div a^n = a^{m-n}$$

$$(a^m)^n = a^{mn}$$

$$\left(\frac{a}{b}\right)^n = \frac{a^n}{b^n}.$$

These laws hold for all types of exponents when $a > 0$, $b > 0$, and some of them for $a < 0, b < 0$. Care must be exercised in their use in this case, especially if fractional exponents occur. An algebraic function of the form ax^n is a power function. A series of the form $a_0 + a_1x + a_2x^2 + \cdots$, with a finite or an infinite number of terms is a **power series.**

POWER AMPLIFICATION. See **amplification, power;** and **power gain.**

POWER ATTENUATION. See **power loss.**

POWER, AVAILABLE. See **available power.**

POWER-BAND MERIT. The product of the output power of an **amplifier** at midband multiplied by the bandwidth of the amplifier measured between points where the **gain** is unity. Not in general use. (See **gain-bandwidth merit.**)

POWER, CARRIER-FREQUENCY, PEAK PULSE. See **peak pulse power, carrier-frequency.**

POWER DETECTOR. A **detector** which can tolerate large signals without distortion.

POWER, ELECTRIC. Electric power is the product of **electric current** and **electromotive force;** that is, multiplication of current by **voltage** forms the basis of the calculation of electric power. In a d-c circuit, the current measured in amperes, multiplied by the voltage between wires, is the power in **watts.** A thousand watts constitutes the kilowatt, a larger and more frequently employed unit of electric power.

The voltage and current may not be in phase with each other in an a-c circuit and, while the instantaneous power is the product of the instantaneous voltage and current, this out-of-phase relation causes the power to fluctuate between positive and negative values. Hence for the average power (which is usually what is desired) this factor needs to be taken into account in determining electric power in an a-c circuit, for it is only that component of the current which is in phase with the voltage that contributes to the average electrical power. The out-of-phase component produces the "wattless power." The **power factor** measures the fraction of the current that is in phase and available for true power. It is equal to the cosine of the phase difference between voltage and current. In a single

phase a-c circuit having current of I amperes, voltage of E volts, and power factor f, the true power is EIf watts. In a balanced three-phase circuit, it is $\sqrt{3}\ EIf$ watts. (See **alternating current, direct current; power, mean.**)

POWER FACTOR. In alternating current networks, the (mean) power is $EI \cos \theta$, where θ is the phase difference between E and I. The multiplying factor, $\cos \theta$, is the power factor.

POWER FLOW, COMPLEX. The complex power flow through a surface is the integral of the normal component of the complex Poynting vector (see **Poynting vector, complex**) over that surface.

POWER GAIN. The ratio of the power that a **transducer** delivers to a specified load, under specified operating conditions, to the power absorbed by its input circuit If the input and/or output power consist of more than one component, such as multifrequency signal or noise, then the particular components used and their weighting should be specified. This **gain** is usually expressed in **decibels.**

POWER GAIN, DYNAMIC. Synonym for **figure of merit** for **magnetic amplifier.**

POWER, LENS. The power of a lens is the reciprocal of its **focal length.** Thus for a thin lens in air

$$\phi = \frac{1}{f} = (n - 1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

where ϕ is the lens power, n is the index of refraction, r_1 and r_2 are the radii of curvature of the lens surfaces Lens power is usually specified in diopters, or meters^{-1}.

POWER LEVEL. At any point in a transmission system, the difference of the measure of the steady state power at that point from the measure of an artibrarily specified amount of power chosen as a reference. In audio techniques, the measures are often expressed in decibels, thus their difference is conveniently expressed as a ratio. Hence, power level is widely regarded as the ratio of the steady state power at some point in a system to an arbitrary amount of power chosen as a reference.

POWER LOSS. The ratio of the power absorbed by the input circuit of a **transducer** to the power delivered to a specified load under specified operating conditions. If the input and/or output power consist of more than one component, such as multifrequency signal or noise, then the particular components used and their weighting should be specified. This **loss** is usually expressed in **decibels.**

POWER, MEAN. The instantaneous power in a device, or branch of a network is EI. The mean power is

$$\frac{1}{T}\int_0^T EI\,dt,$$

where T is an integral number of periods, or T approaches infinity for non-periodic currents. The mean power is also given by

$$P = \bar{I}^2 R,$$

where $\overline{I^2}$ is the mean square current, and R the resistance. (See also **power, electric.**)

POWER OUTPUT, MAXIMUM AVERAGE. The maximum radio-frequency output power which can occur under any combination of signals transmitted, averaged over the longest, repetitive **modulation** cycle.

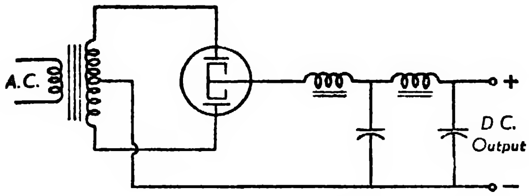
POWER OUTPUT, PEAK. The output power averaged over a **carrier** cycle at the maximum amplitude which can occur with any combination of signals to be transmitted.

POWER, PEAK PULSE. See **peak pulse power.**

POWER, RADIANT. The rate of transfer of radiant energy. (See **energy, radiant.**)

POWER SPECTRUM LEVEL. The **power level** for the acoustic power contained within a band 1 cycle per second wide, centered at the specified frequency. The reference power should be explicitly stated.

POWER SUPPLY. This term is widely used to denote a circuit for converting a-c into d-c by electronic means. The usual power supply consists of a **transformer** for changing the a-c voltage to a value which will, when rectified and filtered, give the desired value of d-c, rectifier tube or tubes, and a **filter** consisting of inductance in series and capacitance in shunt with the d-c line. A typical circuit is shown. The output of the rectifier is pulsat-



ing d-c and hence needs to be smoothed out by the filter before it is suitable for many applications. Power supplies of this type are almost universal components of radios, **amplifiers** and other vacuum-tube devices which operate from a-c mains.

POWER TRANSMISSION RATIO. The ratio of the average acoustic energy transmitted normally through a surface to the average acoustic energy incident normally upon that surface.

POWER, UNITS OF.

(1) Absolute System

a Metric c g sec.

The unit of power is the $\frac{\text{erg}}{\text{sec}}$. By convention, however, the watt $= 1\,\frac{\text{joule}}{\text{sec}}$ is generally used. 1 watt $= 10^7\,\frac{\text{erg}}{\text{sec}}$.

b. Metric m kg sec.

The unit of power is the watt $= 1\,\frac{\text{joule}}{\text{sec}}$.

c. English lbm ft sec.

The unit of power is the ft/lbal/sec $= 5.62 \times 10^{-5}$ horsepower.

(2) Gravitational System

a. English lbf ft sec.

The unit of power is the horsepower = 33,000 ft-lb/min = 550 ft lb/sec.

POWER, VISUAL TRANSMITTER. The peak power output (see **power output, peak**) when transmitting a standard television signal.

POWER WINDINGS. Of a **saturable reactor,** those windings to which the power is supplied by a local source. Commonly the functions of the output winding and the power windings are accomplished by the same winding, which is then termed the output winding. (See also **gate circuit.**)

POYNTING THEORM. Manipulation of the **Maxwell equations** yields a relation known as the Poynting theorem:

$$\int_S (\mathbf{E} \times \mathbf{H}) \cdot \mathbf{n}\,da + \int_V \mathbf{E} \cdot \mathbf{J}\,dV = -\int_V \left\{ \mathbf{E} \cdot \frac{\partial \mathbf{D}}{\partial t} + \mathbf{H} \cdot \frac{\partial \mathbf{B}}{\partial t} \right\} dV,$$

where $\mathbf{n}$ is the unit vector normal to the surface S that bounds the volume V. The customary interpretation of this result is that the right-hand side represents the rate of loss of electric and magnetic energy stored in the volume V, that the second term on the left represents the rate of dissipation of electrical energy as **Joule heat** in V, and that the first term represents the balancing flow of electromagnetic energy through the surface S bounding the volume. It is often convenient to assume that the Poynting vector

$$\mathbf{P} = \mathbf{E} \times \mathbf{H}$$

represents the power flow per unit area in the direction $\mathbf{P}$. This resolution of the total outward power flow is not unique, and is not acceptable when applied to an electrically-charged permanent **magnet,** but is notably successful in treating **electromagnetic radiation problems.**

POYNTING-ROBERTSON EFFECT. Tangential drag force on a body moving around the sun due to the absorption of radiation from the sun and causing the body to spiral inwards. The rate of decrease per year of the major axis a (astronomical units) of a body of radius r cm, density ρ g cm^{-3} is $-7 \times 10^{-8}(\rho a r)^{-1}$ from this effect and is therefore negligible for planets and planetoids.

POYNTING VECTOR. See **Poynting theorem.**

POYNTING VECTOR, COMPLEX. When the electromagnetic field vectors $\mathbf{E}$ and $\mathbf{H}$ are represented with complex **amplitudes,** the **Poynting vector** ($\mathbf{P} = \mathbf{E} \times \mathbf{H}$) is generalized to the complex Poynting vector

$$\tfrac{1}{2}\mathbf{E} \times \mathbf{H}^*;$$

its real part is the average power flow per unit area.

PPI. Abbreviation for **plan-position indicator.**

PPPI. Abbreviation for **precision plan-position indicator.**

P³I. Abbreviation for **precision plan-position indicator.**

P'I. Abbreviation for **photographic projection plan-position indicator.**

PRACTICAL UNITS. The common units (**volt, ampere, farad,** etc.) defined by multiplying the **cgs electromagnetic units** by suitable powers of ten. They can also be defined as the fundamental units of the **MKSA electromagnetic system.**

PRASEODYMIUM. Rare earth metallic element. Symbol Pr. Atomic number 59.

PRANDTL NUMBER. The kinematic viscosity (see **viscosity, kinematic**) of a fluid divided by its thermal conductivity. Its significance arises from the interpretation of the kinematic viscosity as a **diffusion coefficient** for **momentum** or **vorticity** and of the thermal conductivity as the diffusion coefficient for heat.

PRECESSION. An effect manifested by a rotating rigid body when a **torque** is applied to it in such a direction that the orientation of the axis of rotation would change in the absence of **angular momentum.** If the speed of rotation and the magnitude of the applied torque are constant, the axis, in general, slowly describes a cone, its motion at any instant being at right angles to the direction of the torque.

A familiar example of precession is an ordinary symmetrical spinning top. If the axis of spin is not exactly vertical, the force of gravity exerts a torque tending to overturn the top; but instead of tipping over, it "wobbles" with a precessional motion about the vertical through the pivotpoint. The **gyroscope** exhibits similar behavior. The period of precession is given by

$$T_p = \frac{4\pi^2 I_s}{QT_s}$$

in which I_s is the moment of inertia about the axis of spin, Q is the torque due to gravity, and T_s the period of the spin (see also **Larmor precession**).

PRECIPITATION, CONVECTIONAL. Precipitation from clouds caused by thermal instability, i.e., clouds of the **cumulus** or **cumulonimbus** type.

PRECIPITATION HARDENING. Directly after quenching, an alloy in the form of a supersaturated **solid solution** is mechanically soft, but becomes harder as precipitation of the excess component proceeds. Later, with over-aging, it resoftens. According to the theory of Mott and Nabarro, the effect is due to the resistance offered to the passage of **dislocations** by the internal stresses caused by the misfit of the precipitate particles. As these become larger, and further apart, the dislocation lines can bulge round them, and move more easily again.

PRECISION. Quality of being exactly or sharply defined or stated. A measure of the precision of a representation is the number of the distinguishable alternatives from which it was selected. The precision of measurement is the degree of reproducibility among several independent measurements of the same true value under specified conditions.

PRECISION INDEX. See **error function.**

PRECONDUCTION CURRENT. The small value of electrode current in a **gas-discharge tube** before a **self-maintained discharge** is initiated.

PREDISSOCIATION. A process by which a molecule that has absorbed energy dissociates before it has had an opportunity to lose energy by radiation.

PRE-EMPHASIS. (1) A process in a system to emphasize the magnitude of some frequency components with respect to the magnitude of others. (2) The intentional alteration of the normal signal wave by emphasizing one range of frequencies with respect to another. For example, pre-emphasis in **recording** is an arbitrary change in the frequency-response of a recording system from its basic response (such as constant velocity or amplitude) for the purpose of improvement in **signal-to-noise ratio,** or the reduction of **distortion.**

PRE-EMPHASIS NETWORK. See **network, pre-emphasis.**

PREFERRED NUMBERS. To maintain an orderly progression of sizes, preferred numbers are frequently used for the **nominal**

values. A further advantage is that all components manufactured are salable as one or another of the preferred values. Each preferred value differs from its predecessor by a constant multiplier, and the final result is conveniently rounded to two significant figures.

The ASA has adopted as an "American Standard" a series of preferred numbers based on $\sqrt[5]{10}$ and $\sqrt[10]{10}$. This series has been widely used for fixed wirewound power-type resistors and for time-delay fuses.

Because of the established practice of ± 20, ± 10, -- and ± 5-percent tolerances in the radio-component industry, a series of values based on $\sqrt[6]{10}$, $\sqrt[12]{10}$, and $\sqrt[24]{10}$ has been adopted by the RMA, and is widely used for small radio components, as fixed composition resistors and fixed ceramic, mica, and molded-paper capacitors.

PREFERRED VALUES. See **preferred numbers.**

PRE-FIRING. Pre-firing refers to the interval during the output or **gating** alternation preceding **firing.** The term is used as an adjective to indicate phenomena occurring during this interval.

PRE-SELECTOR. A **pre-amplifier** placed between the antenna and a radio-receiver to increase the effective **sensitivity** and **selectivity** of the receiver.

PRESET, FLUX. Synonym for **flux reset.**

PRESSING. A phonograph record, especially one made by a pressing process from a stamper.

PRESSURE. A type of stress, characterized by its uniformity in all directions (as distinguished from compressive stress in one direction). Its measure, as with all other stresses, is the force exerted per unit area; for example, the normal **atmospheric pressure** is about 14.7 lbf per sq in. Pressure is usually associated with a decrease in volume; though the opposite stress, accompanying an increase in volume, is sometimes referred to as "negative pressure." This latter must be distinguished from the same term as sometimes used to denote pressures below atmospheric, the pressure of the atmosphere being in such cases taken as an arbitrary zero. It is likewise important, especially in pneumatics, to indicate whether pressure is reckoned from vacuum or from atmospheric pressure as zero. Thus when a tire is inflated to "thirty-five pounds," the actual pressure in the tire is about 50 lbf per sq in. Pressure may be defined analytically as that part of the **stress** tensor that does not depend directly on the rate of strain and which arises from the molecular movements appropriate to the local density and temperature, i.e., the pressure satisfying the equation of state. In a compressible Newtonian fluid (see **fluid, Newtonian**), the stress tensor is

$$p_{ij} = \eta\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) - \left(\frac{2}{3}\eta' \frac{\partial u_i}{\partial x_i} + p\right)\delta_{ij}$$

where η is the ordinary viscosity, and η' is the second coefficient of viscosity. In agreement with the definition above, the pressure p contributes only to the normal stresses.

PRESSURE, ABSOLUTE. The term applied to the true pressure of a substance or system, commonly to distinguish it from partial pressure, gauge pressure, etc.

PRESSURE, ATMOSPHERIC. The normal atmospheric pressure, or pressure of one atmosphere, is 1.013×10^6 dynes per square centimeter or about 14.7 pounds per square inch. This will support a column of mercury (in a barometer) 76 centimeters high at 0°C.

PRESSURE, COHESION. The correction applied to the pressure term in the **van der Waals' equation** to take care of the effect of **molecular attraction.** It is usually expressed as a/V^2, where a is a constant and V is the volume of the gas.

PRESSURE EFFECT ON SPECTRAL LINES. See **pressure shift** and **pressure broadening.**

PRESSURE, GAUGE. Pressure measured relative to atmospheric pressure taken as zero.

PRESSURE, IMPACT. Pressure exerted by a moving fluid on a plane perpendicular to its direction of flow. In other words, it is measured *in* the direction of flow.

PRESSURE, INTERNAL. The attractions between the molecules of a substance produce the same effect as an added external pressure,

the internal pressure. In liquids, its effect appears as the ability of liquids to withstand substantial negative pressures without rupture.

PRESSURE MEASUREMENT, NULL METHOD OF. A method of sound pressure measurement, due to Gerlach, in which the sound pressure on a diaphragm is compensated by measurable electrodynamic forces so that the diaphragm remains at rest under the two forces.

PRESSURE MEASUREMENT, SMITH METHOD OF. A method of sound pressure measurement in which a balance is obtained between the effect produced by the sound in a sensitive **amplifier** connected to the receiver and the effect of a known small emf of the same sound frequency.

PRESSURE MICROPHONE. See **microphone, pressure.**

PRESSURE MULTIPLIER. A device in which the pressure of a sample of gas, in a high-vacuum system, is amplified, for example by reducing its volume (**McLeod gauge**), so as to permit easy determination of the pressure.

PRESSURE, NEGATIVE. Strictly, a normal stress that tends to increase the volume of the substance (cf. **pressure**). The term is often used, however, to indicate a negative gauge pressure, i.e., a pressure that is less than atmospheric, or a pressure less than 760 millimeters of mercury at 0°C.

PRESSURE, PARTIAL. The pressure that is exerted by a single gaseous **component** of a mixture of gases.

PRESSURE SHIFT AND PRESSURE BROADENING. Spectrum lines are subject to various physical influences brought to bear upon the substance emitting the radiation, and among these is pressure. When the pressure and density of a gas are greatly increased, the lines of its spectrum become less sharp, or broader (without change of total intensity). This broadening is not symmetrical but is greater in the direction of longer wavelength, so that the peak or maximum is shifted toward the red.

PRESSURE, STANDARD. The pressure exerted by a column of mercury 760 millimeters high at 0°C.

PRESSURE, STATIC. (1) Pressure in a fluid or system that is exerted normal to the surface on which it acts. In a moving fluid, the static pressure is measured at right angles to the direction of flow. (2) In acoustics, the static pressure at a point in a medium is the pressure that would exist at that point with no sound waves present. In acoustics, the commonly used unit is the **microbar.**

PRESSURE-TYPE CAPACITOR. See **capacitor, pressure-type.**

PRESSURE, UNITS OF. The unit of pressure in the cgs system is the dyne cm^{-2}. In meteorology, the **millibar,** equal to 10^3 dyne cm^{-2} is often used. In engineering practice, the units of lbf $in.^{-2}$ (psi) and atmosphere ($1.013 \cdot 10^6$ dyne cm^{-2}) are used, as well as **heads** expressed in terms of water or mercury.

PRESSURE, VELOCITY. The component of the pressure of the moving fluid that is due to its velocity and is commonly equal to the difference between the impact pressure and the static pressure. (See **pressure impact,** and **pressure, static (1).**)

PREVAILING WESTERLIES. Winds that blow toward the poles from the **horse latitudes.** They are not as steady as the **trade winds** in the Northern Hemisphere, but are more constant in the Southern Hemisphere, where they are known as the "Roaring Forties."

PREVAILING WESTERLIES, LONG WAVES IN. There develop in the westerlies, particularly during the cold months of the year, certain perturbations which cause the westerlies to blow alternately northward and southward in a sinusoidal wave pattern, but always with a component of velocity directed from west to east. Wave crests are associated with **anticyclones** at ground and near ground levels, whereas troughs are associated with **cyclones.** There is, therefore, a definite relation between the sinusoidal perturbations of the westerlies and large-scale surface weather phenomena.

PREVOST LAW OF EXCHANGES. (1) In an evacuated enclosure, with walls maintained

at constant temperature, objects within will reach a condition of thermal equilibrium at which they will attain, and remain at, the temperature of the walls. (2) Each body is constantly exchanging heat energy with its surroundings, the net result of which exchange tends to equalize the temperature of the body and its surroundings. Cold bodies do not radiate cold, they only radiate less heat than they receive from warmer surroundings.

PRIMARY CELL. See **cell, primary.**

PRIMARY COLOR(S). The colors of constant **chromaticity** and variable **luminance** which, when mixed in proper proportions, are used to produce or specify other colors. Primaries need not be physically realizable.

PRIMARY COSMIC RAYS. See **cosmic rays.**

PRIMARY DARK SPACE. Another name for the **Aston dark space.**

"PRIMARY EXTINCTION." When **X-rays** are diffracted by a very perfect crystal, in which the **mosaic** blocks are very large, there is a relative weakening of the strongest reflections compared with the weaker. More precisely, the **structure factor** is directly proportional to the intensity of the beam in a perfect crystal, whilst for a mosaic crystal it is proportional to the square root of the intensity.

PRIMARY FLOW (OF CARRIERS). A current flow which is responsible for the major properties of a **semiconductor device.**

PRIMARY FOCUS. See **astigmatic focus.**

PRIMARY ION PAIR. See **ion pair, primary.**

PRIMARY SKIP ZONE. That area surrounding a **transmitter** which is beyond ground-range, but where sporadic **skip transmission** may be received.

PRIMARY WINDING. Any winding of a **transformer** used as the input port for power is called the "primary" winding Transformers designed for specific applications often have one set of terminals labeled "primary" to indicate normal usage.

PRIMITIVE. Given a function of one or more arbitrary constants or functions, the constants may be eliminated by direct differentiation one or more times, or the constants and functions may be eliminated by differentiation and algebraic operations. The result in either case is a **differential equation** and the given function is its primitive or general solution.

PRIMITIVE PERIOD. Defined in entry for **periodic quantity.**

PRIMITIVE TRANSLATION. A **space lattice** has the property of exactly repeating itself if it is carried through any one of a number of different translations in space. These translations may all be constructed by the repeated application of three primitive translations, which thus constitute the sides of the **unit cell** of the lattice.

PRINCIPAL AXIS. (1) The longest axis of a **crystal.** (2) The **optical axis** of a crystal. (3) Mathematically, any one of the set of axes in terms of which a quadratic function may be expressed as a sum of squares. (4) Of a **transducer** used for sound emission or reception, a reference direction for angular coordinates used in describing the directional characteristics of the transducer. It is usually an axis of structural symmetry, or the direction of maximum response. (5) For the use of the term in mechanics, see **inertia, moments and products of.**

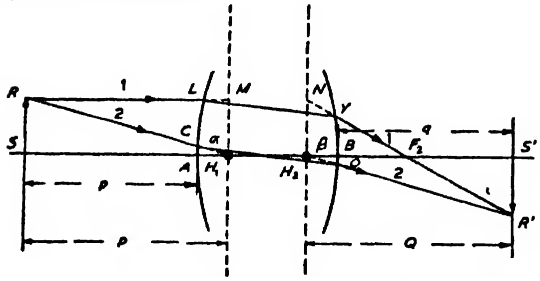
PRINCIPAL E PLANE. In electromagnetics, a plane containing the direction of maximum radiation, and in which the electric vector everywhere lies in the plane.

PRINCIPAL H PLANE. In electromagnetics, a plane containing the direction of maximum radiation, and in which the electric vector is everywhere normal to the plane, while the magnetic vector lies in the plane.

PRINCIPAL PLANE (CRYSTAL). For a ray of light traversing a **double-refracting** crystal, the principal plane is determined by the direction of the ray and the axial direction of the crystal.

PRINCIPAL PLANE (LENS). Two planes so located in a thick lens or lens system such that if object distances are measured from the first principal plane and image distances are measured from the second principal plane, the **thin-lens formulae** will hold. The inter-

sections of the principal planes with the optical axis are the principal points of the lens or system of lenses.



H_1 and H_2 are the principal points; MH_1 and NH_2 the principal planes of a thick lens In locating images by a graphical method, principal rays may be used as for thin lenses if the incident light falls on an imaginary thin lens coincident with the first principal plane, the lens being shifted to coincide with the second principal plane for the emergent light (By permission from "Introduction to Optics, Geometrical and Physical" by Robertson, 4th Ed, Copyright 1954, D. Van Nostrand Co., Inc)

PRINCIPAL POINTS. The intersections of the **principal planes (lens)** with the optical axis.

PRINCIPAL SECTION OF A CRYSTAL. A plane through a crystal which contains the **optic axis** of the crystal and the ray of light under consideration.

PRINCIPAL SERIES. See **series in line spectra.**

PRINCIPLE OF CORRESPONDENCE. A statement by Bohr of the assumption that in the limit, for very low frequencies of radiation, the results obtained by quantum theory must be in quantitative agreement with those obtained on the basis of classical theory. According to this principle, the predictions of quantum theory must coincide with those of classical theory for sufficiently high quantum numbers.

PRINCIPLE OF EQUIVALENCE OF MASS AND ENERGY. See **mass-energy equivalence.**

PRINT-OUT EFFECT. The appearance of metallic silver in a silver halide emulsion after prolonged exposure to light. It is believed that the light l berates electrons which go to the specks of silver already present, attracting to them further silver ions whilst the halogen escapes to the surface.

PRINT-THROUGH. A type of distortion sometimes present in **magnetic tape recordings** which is due to one strongly-magnetized layer of tape "printing" its magnetic image on adjacent layers of tape.

PRINTED CIRCUIT. Any circuit formed by depositing a conducting material on the surface of an insulating sheet. This may be achieved by the use of electrically conducting ink, electroplating, etc.

PRIONOTRON. One form of **velocity-modulation tube.**

PRISM. (1) A **polyhedron** with two congruent and parallel faces, the bases. Its other faces, called lateral, are produced by drawing lines from the vertices of the bases and they are therefore parallelograms. The prism is named triangular, quadrangular, etc., descriptive of its base. (2) Glass and other transparent materials are cut into many different forms of prism for various optical purposes. Incident light may pass directly through a prism, or may emerge after one or more internal reflections; in some cases it is **polarized.**

The common triangular prism, familiar in older forms of **spectroscope,** receives light upon one face and passes it through another after two refractions, resulting in a total deviation Δ dependent upon the angle of the prism and its **refractive index** for the light used. If the light is incident at angle i on the first prism face, and if the prism angle is α and the refractive index is n, the total deviation after passage through the prism in a plane at right angles to the prism edge is given by

$$\Delta = i - \alpha + \sin^{-1}\left[n \sin\left(\alpha - \sin^{-1}\frac{\sin i}{n}\right)\right].$$

(See also **prism, Amici; prism, Cornu-Jellet; prism, Féry; prism, roof,** etc.)

PRISM, AMICI. A direct-vision **prism,** that is, a prism combination by which a beam of light is dispersed into a spectrum without mean deviation. Such prisms are sometimes used in direct-vision **spectroscopes.**

The principle will be clear from the following example. Assume an inverted prism of crown glass with an angle of 40°, used with an erect prism of flint glass. Yellow sodium light (5893 A) is deviated by the crown-glass prism through +22° 32′ (upward). For the

flint-glass prism to produce an equal negative (downward) deviation it must have an angle of 33° 40′. (Each prism is supposedly set for minimum deviation.) Together they produce no deviation for this wavelength. But if light of 7682 A (red) is used, the deviation of the crown glass is +22° 16′, while that of the flint is −22° 10′, giving a net deviation of +6′. And for the wavelength 4047 A (violet), the deviations are, respectively, +23° 12′ and −23° 44′, giving −32′. There is thus, between the ends of the visible spectrum, a separation of 38′. Additional pairs of prisms may be used to increase the dispersion. More commonly 2 crown and one flint prisms are used, thus reducing surface reflection at the air-glass interfaces. (Also see **prism, roof.**)

PRISM, BRASHEAR-HASTINGS. A type of roof prism (see **prism, roof**) which has the desirable property of being able to invert an image without producing deviation or displacement of the beam. Because of manufacturing difficulties, this prism is seldom made.

PRISM, CONSTANT-DEVIATION. A **prism** which refracts any required wavelength at minimum **deviation** in a prescribed direction to that of the incident beam. (See also **prism, Pellin-Broca.**)

PRISM, CORNU DOUBLE. In order to make use of the ultraviolet-transmitting properties of quartz without introducing its double refraction, Cornu made a compound prism by cementing together two 30-degree prisms, one of right-handed and one of left-handed quartz.

PRISM, CORNU-JELLET. A **prism** made by splitting a Nicol (see **prism, Nicol**) in a plane parallel to the direction of vibration of the transmitted light and removing a wedge-shaped section. When the two pieces are joined together again, the planes of vibration of the light transmitted by the two halves make a small angle with each other.

PRISM, DOUBLE IMAGE. See **prism, Wollaston double image.**

PRISM, DOVE (REVERSING PRISM). A **prism** which has the property of inverting a beam of light. Three faces are polished, and the size and index of refraction must be properly correlated if the beam is not to be displaced laterally. Rotation of the prism about the axis of the beam rotates the beam at twice the rate of rotation of the prism.

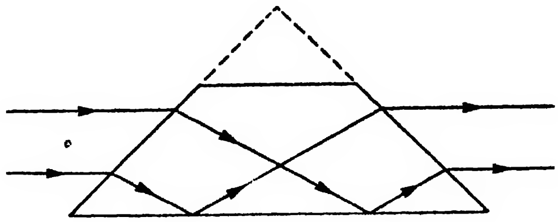


Diagram of dove prism

PRISM, FÉRY. A prism, widely used in making **spectrographs,** which **collimates, reflects** and refracts the refracted light-rays. The Féry prism has spherical-ground and coated surfaces.

PRISM, FOUCAULT. A polarizing **prism** of calcite similar to a Nicol prism (see **prism, Nicol**) but with the two parts separated by a thin air film, and cut to such angles that the extraordinary beam will be transmitted, and the ordinary beam, totally-reflected. A Foucault prism is never as efficient as a Nicol prism because some of the extraordinary beam will also be reflected.

PRISM, FRESNEL BIPRISM. A very flat prism with two very acute angles and one very obtuse angle. A device developed for obtaining **interference** between two sections of a wave front, with **diffraction** largely eliminated.

PRISM, GLAN. Also known as Glan-Thompson prism. A polarizing **prism** somewhat like a Nicol prism (see **prism, Nicol**) but with faces normal to the axis, and with the two parts separated by a glycerin film.

PRISM, LIPPICH. A type of half-shade analyzer consisting of a small Nicol prism (see **prism, Nicol**) covering half the field of a polarimeter.

PRISM, LITTROW. A 30–60–90 degree **prism** silvered on the side opposite the 60 degree angle. A single lens can then be used as both **collimator** and **telescope.**

PRISM, NICOL. One of the best known devices for producing plane-**polarized light.** It

consists of two pieces of Iceland spar (pure calcium carbonate) cut as shown in the figure. The optic axis of each is approximately

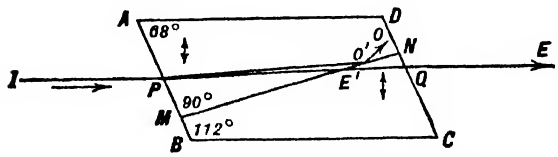
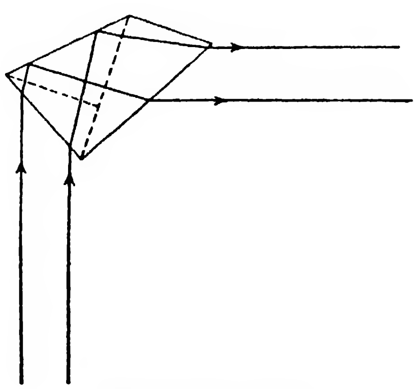


Diagram of Nicol prism Double-headed arrows indicate direction of optic axis

indicated by the double arrow, and they are cemented together with colorless Canada balsam along the plane MN. If the incident beam IP is unpolarized, it suffers **double refraction** at P, dividing into an ordinary component PO' and an extraordinary component PE'. The refractive index of Iceland spar for the ordinary ray (sodium light) is 1.658 and for the extraordinary it is 1.486, while that of Canada balsam for both is 1.53 The ordinary ray therefore encounters at O' a less refractive medium, and, the incidence being at an angle larger than the critical angle, it is totally reflected ($O'O$); while the extraordinary ray incident at E' encounters a more refractive medium, therefore cannot suffer total reflection and most of it passes on along $E'Q$, emerging along QE completely plane-polarized with its vibration plane in the plane of the paper. Modifications of this prism, having different shapes and using other cements, have been designed for special purposes.

PRISM, PELLIN-BROCA. A constant-deviation prism (see **prism, constant-deviation**),



Pellin-Broca prism

consisting of two 30° prisms, connected by a 45° total-reflecting prism. (See **prism, total-reflecting.**)

PRISM, PENTA. A five-sided optical **prism** of which one angle is 90°, and the other four are 112° 30′ each.

PRISM, PORRO. A triangular optical **prism** having one 90° and two 45° angles. Two of these are used in each telescope of the prism binoculars. Light enters perpendicular to the hypotenuse, and, after two **internal reflections,** leaves by the same face.

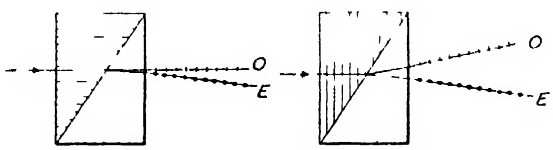
PRISM, RESOLVING POWER OF. The resolving power of a prism (to resolve near-by spectral lines) is given by

$$R = (\text{Base of Prism})(dn/d\lambda)_\lambda$$

where $(dn/d\lambda)_\lambda$ is the rate of change of refractive index with wavelength, in the wavelength-region under consideration.

PRISM, RISLEY. Two wedge-shaped **prisms** made so as to rotate with respect to each other, to give a single prism of any angle between the sum of the two prisms and their difference.

PRISM, ROCHON (WOLLASTON PRISM). Nicol prisms cannot be used in ultraviolet light as the Canada balsam is not transparent to these shorter wavelengths. The Rochon and Wollaston prisms are made of quartz or calcite and "cemented" with glycerine or castor oil.



Rochon and Wollaston prisms

The direction of the optic axis of each crystal is indicated by the shading. The Rochon prism transmits the ordinary ray without deviation, the ray being achromatic. The light should travel through the prisms in the directions indicated.

PRISM, ROOF. A total-reflection prism (see **prism, total-reflection**) in which the surface opposite the right angle has been replaced by two surfaces at right angles (roof), with their common element parallel to the hypotenuse of the triangle. The roof prism turns the beam through 90° like a total-reflection prism, and also inverts the beam like a Dove prism.

Roof prisms are sometimes called Amici prisms, as are also direct vision spectroscope prisms, which are very different from roof prisms.

PRISM, THIN, FORMULA. For prisms of angle sufficiently small that the sine of the angle may be replaced by the angle itself, the customary minimum deviation formula reduces to:

$$\delta = (n - 1)\alpha$$

where δ is the angle of deviation, and α is the refracting angle of the prism.

PRISM, THOLLON. (1) Two 30° prisms which rotate by equal angles in opposite directions to give constant deviation (see **prism, constant-deviation**). (2) A compound, spectroscopic prism consisting of two acute-angled prisms cemented to a right-angled one, giving great dispersion without the use of a train of prisms.

PRISM, TOTAL-REFLECTING. A 45–45–90° prism like a Porro prism (see **prism, Porro**) in construction. The light enters normally to a face opposite to a 45° angle, is totally reflected by the hypotenuse face, and leaves by the third face, thus having been totally reflected through 90°. The beam of light must be sufficiently parallel so that all of the light strikes the reflecting face outside of the **critical angle**, or the reflection will not be total.

PRISM, WOLLASTON. Discussed under **prism, Rochon.**

PRIVILEGED DIRECTIONS. When a plane-polarized beam falls on a thin plate of an anisotropic material which is not optically active, there are in general two and only two mutually-perpendicular directions for the **plane of polarization** (privileged directions) such that the emergent beam is also plane-polarized. With other orientations of the polarization of the entrant beam, the emergent beam is circularly or elliptically polarized. (See **light, plane-polarized**; and **light, elliptically-polarized.**)

PROBABILITY AMPLITUDE. The eigenfunctions ϕ obtained by solving the **Schroedinger wave equation.** (See also **probability density.**)

PROBABILITY DENSITY. The quantity

$$\Phi\Phi^* dr = |\Phi|^2 dr = |\Phi^*|^2 dr$$

where Φ is the Schroedinger wave function, Φ^* is its complex conjugate, and ϕ is the corresponding **eigenfunction.** As was postulated by Born, the quantity set out above gives the probability that the particle under consideration will be found in the volume element dr at the position given by the coordinates.

PROBABLE ERROR. A measure (pe) of the uncertainty of an experimentally determined quantity, such that the "true" value of the quantity is equally likely to depart from the measured value by more or less than pe. If the accidental errors are distributed according to the normal **error function** the probable error is defined by the integral equation

$$\operatorname{erf}(pe) = \frac{2}{\sqrt{\pi}} \int_0^{pe} e^{y^2} dy = \tfrac{1}{2}.$$

The other commonly used measures, the **average deviation** a.d. and the **standard deviation** σ are then related to the probable error:

$$pe = 0.846 \text{ a.d.} = 0.674\sigma.$$

PROCA EQUATIONS. One of the four inequivalent sets of equations to describe particles of spin unity, developed by analogy with the **Maxwell equations** for free space.

$$\kappa F_{\mu\nu} = \frac{\partial A_\nu}{\partial x_\mu} - \frac{\partial A_\mu}{\partial x_\nu}; \quad \kappa A_\nu = \frac{\partial F_{\mu\nu}}{\partial x_\mu},$$

κ being proportional to the mass of the particle.

PRODUCT DEMODULATOR. See **demodulator, product.**

PRODUCT, INFINITE. An expansion of the form

$$u_1 u_2 u_3 \cdots u_n \cdots = \prod_{k=1}^{\infty} u_k.$$

The partial products form a sequence $\{p_n\}$ such that

$$p_1 = u_1; \quad p_2 = u_1 u_2; \quad p_3 = u_1 u_2 u_3;$$

$$\cdots \quad p_n = \prod_{k=1}^{n} u_k.$$

PRODUCT, INNER. Often used for the **scalar product of vectors** but more frequently

for a kind of tensor product. Thus the inner product of $\mathbf{A}^{ij}$, a contravariant tensor of rank two, and $\mathbf{B}_{jpq}$, a covariant tensor of rank three, yields a mixed tensor, $\mathbf{C}_{pq}{}^{i}$. This process of removing a repeated index is called **contraction.**

PRODUCT, OUTER. Sometimes meaning the **vector product** of two vectors but more often used for a tensor product. The outer product of a contravariant tensor, $\mathbf{A}^{i}$, by a covariant vector, $\mathbf{B}_{j}$, is a mixed tensor of rank two, $\mathbf{A}^{i}\mathbf{B}_{j} = \mathbf{C}^{i}{}_{j}$. It is easy to show that the outer product transforms like a mixed tensor. The process may be extended for tensors of any rank, thus $\mathbf{A}^{m}{}_{n}\mathbf{B}_{pq} = \mathbf{C}^{m}{}_{npq}$.

PROGRAM. (1) A set of **instructions** arranged in proper sequence to instruct a **digital computer** to perform a desired operation (or operations), such as the solution of a mathematical problem or the collation of a set of data. (2) To prepare a program (contrast with "to **code**").

PROGRAM, CODED. A description of a procedure for solving a problem by means of a **digital computer.** It may vary in detail from a mere outline of the procedure to an explicit list of instructions coded in the machine's language.

PROGRAM LEVEL. The measure of the **program signal** in an audio system expressed in **vu.**

PROGRAM SIGNAL. In audio systems and components, the complex electric waves corresponding to speech, music, and associated sounds, destined for audible reproduction.

PROGRESSION. A sequence, successive terms of which are formed according to a given law. (See **arithmetic, geometric, harmonic progression.**)

PROGRESSIONS (IN BAND SPECTRA). A series of bands whose separation changes rather slowly, found in most molecular spectra.

PROGRESSIVE FREE WAVE. See **wave, free progressive.**

PROGRESSIVE INTERLACE. A system of **interlace** in which all odd lines are scanned in one **field,** and all even lines are scanned in the next field. The standard television transmission in the United States employs this system.

PROGRESSIVE SCANNING. A rectilinear **scanning** process in which the distance from center to center of successively scanned lines is equal to the nominal line width. (See **line width, nominal.**)

PROJECTIVE FIELD THEORIES. See **field theories, projective.**

PROJECTOR EFFICIENCY. See **transmitting efficiency.**

PROJECTOR POWER RESPONSE. See **response, transmitting power.**

PROJECTOR, SPLIT. A directional sound projector in which electroacoustic **transducer** elements are so divided and arranged that each division may be energized separately through its own electric terminals.

PROLATE. Elongated in the direction of a line joining the poles.

PROLATE SPHEROIDAL COORDINATES. The coordinate surfaces are families of prolate **ellipsoids** of revolution around the Z-axis with semiaxes $a = c\xi$, $b = c\sqrt{\xi^2 - 1}$, $\xi =$ const.; **hyperboloids** of revolution of two sheets with $a = c\eta$, $b = c\sqrt{1 - \eta^2}$, $\eta =$ const. and planes from the Z-axis, $\phi =$ const. The coordinates are limited in range:

$$-1 \leq \eta \leq 1; \quad 1 \leq \xi \leq \infty; \quad 0 \leq \phi \leq 2\pi$$

and in terms of rectangular coordinates:

$$x = c\sqrt{(1 - \eta^2)(\xi^2 - 1)} \cos \phi;$$

$$y = c\sqrt{(1 - \eta^2)(\xi^2 - 1)} \sin \phi;$$

$$z = c\xi\eta.$$

The variables

$$\xi = \cosh u; \ \eta = \cos v; \ 0 \leq u \leq \infty; \ 0 \leq v \leq \pi$$

are often used.

This system is particularly useful in quantum mechanical two-center problems, for if the centers are taken at the foci of the system, the focal radii to a point where the surfaces of revolution intersect satisfy the relations

$$r_1 + r_2 = 2c\xi$$

$$r_1 - r_2 = 2c\eta.$$

PROMETHIUM. Radioactive element. Symbol Pm. Atomic number 61.

PROMPT CRITICAL. Capable of sustaining a **chain reaction** without the aid of delayed **neutrons.**

PROMPT NEUTRONS. Those neutrons released coincident with the **fission** process, as opposed to the neutrons subsequently released.

PROPAGATION CONSTANT. A transmission characteristic of a **line** or medium, which indicates the effect of the line on the wave being transmitted along the line. It is a complex quantity having a real term, the attenuation constant, and an imaginary term, the wavelength or phase constant. The attenuation constant is a measure of the loss in signal strength as the wave travels along a matched line while the wavelength constant is a measure of the phase shift which it undergoes. These relations may be expressed by the following equations:

$$r = a + jB, \quad E_r = E_s\epsilon^{-(a+jB)}$$

$$|E_r| = |E_s|\epsilon^{-al}$$

$$|I_r| = |I_s|c^{-al}$$

$$\text{Phase displacement} = Bl$$

where r is the propagation constant, a the attenuation constant, B the wavelength constant, l the line length, E_r the received voltage, E_s the sending end voltage and I the corresponding currents. Because of the attenuation on lines used for communication purposes it is necessary to insert **amplifiers** or repeaters at intervals to build the signal back to suitable levels. For sound work the phase shift is usually not important but for **television** and picture transmission it is extremely important and necessitates correcting circuits.

PROPAGATION, DIRECTION OF. At any point in a homogeneous, isotropic medium, the direction of time-average energy flow.

PROPAGATION FACTOR. See **propagation ratio.**

PROPAGATION RATIO. For a wave propagating from one point to another, the ratio of the complex **electric field strength** at the second point to that at the first point.

PROPAGATION, STANDARD. The **propagation of radio waves** over a smooth spherical earth of uniform dielectric constant and conductivity, under conditions of standard refraction in the atmosphere.

PROPER LENGTH. The length of a body relative to an observer to whom the total momentum of the body is zero. For a body whose parts are not in relative motion, the observer is then at rest relative to the body as a whole.

PROPER LORENTZ TRANSFORMATION. A **Lorentz transformation** which may be represented by an orthogonal operator with determinant +1. This then excludes transformations which reverse the sense of an odd number of the axes x, y, z, t

PROPER TIME. Time coordinate of a system in the **Lorentz frame** in which the total momentum of the system is zero. For a particle, this becomes the **Lorentz frame** in which the particle is at rest.

PROPER VOLUME. The volume of a body relative to an observer to whom the total momentum of the body is zero.

PROPERTY. That which is inherently characteristic of a substance and naturally essential to it.

PROPERTY, ADDITIVE. A property of a system that is equal to the sum of the values of that property for the constituents of the system.

PROPERTY, COLLIGATIVE. A property that depends for the most part on the number of molecules involved and not on their nature.

PROPERTY, CONSTITUTIVE. A property that depends for the most part on the arrangement of the atoms in the molecule and, to a lesser degree, on their number and nature.

PROPERTY, EXTENSIVE. A property of a system that varies in its value with the quantity of material contained in the system.

PROPERTY, INTENSIVE. A property of a system that is independent of the quantity of material contained in the system.

PROPERTY, POLAR. A property of a system relating to a partial separation of electric charges of opposite sign.

PROPORTION. A statement of equality between two **ratios.** It may be written in the

form $a:b = c:d$ or $a/b = c/d$. In a proportion $a:b = c:d$, the first and fourth numbers, a and d, are the extremes and the second and third ones, b and c, are the means of the proportion. The following relations, all of which follow from $a/b = c/d$, are sometimes useful.

(1) $$b/a = d/c;$$

(2) $$a/c = b/d;$$

(3) $$(a \pm b)/b = (c \pm d)/d;$$

(4) $$a/(a - b) = c/(c - d);$$

(5) $$(a \pm b)/(a \mp b) = (c \pm d)/(c \mp d).$$

PROPORTION OF POLARIZATION. Light is only partially polarized when it is passed through a pile of plates. The proportion of polarization is given by:

$$PP = \frac{I_p - I_s}{I_p + I_s}$$

where I_p is the intensity of the light vibrating parallel to the plane of incidence and I_s is the intensity of the light vibrating perpendicular to the plane of incidence. For a single surface the proportion of polarization is only about 8.1%. For m plates ($2m$ surfaces) of refractive index n,

$$PP = \frac{m}{m + \left(\frac{2n}{1 - n^2}\right)^2}.$$

PROPORTIONAL COUNTER. A radiation **counter** designed to operate in the **proportional region.**

PROPORTIONAL LIMIT. The maximum unit **stress** which can be obtained in a structural material without causing a change in the ratio of the unit stress to the unit **deformation** is called the proportional limit.

PROPORTIONAL REGION. In radiation **counter** usage, the range of applied voltage in which the gas amplification exceeds 1 and is independent of the charge liberated by the **initial ionizing event.** This region depends on the type and energy of the radiation, and is distinct from the Geiger region.

PROTACTINIUM. Radioactive element. Symbol Pa. Atomic number 91.

PROTIUM. The name sometimes given to the lighter isotope of **hydrogen,** which consists of a single proton and electron, has an atomic number of 1 and a mass number of 1, and constitutes about 99 98% of ordinary hydrogen.

PROTON. (1) A positively charged elementary particle of mass number 1 and charge equal in magnitude to the electronic charge e. It is one of the constituents of every nucleus; the number of protons in the nucleus of each atom of an element is given by the atomic number Z of the element. Other properties of the proton are: rest mass, 1.67×10^{-24} gm, or 1.0075 amu; magnetic moment, 2.79245 nuclear magnetons, or 1.52×10^{-3} dyne cm gauss^{-1}; spin quantum number, ½; described by Fermi-Dirac statistics. (2) The nucleus of an atom of hydrogen of mass number 1. (3) The negative proton is discussed under **anti-proton.**

PROTON-PROTON CHAIN. A series of **thermonuclear reactions** initiated by a reaction between two protons, namely $H^1 + H^1 \rightarrow H^2 + \beta + \nu$, that provides the energy of some stars. The subsequent reactions are presumed to be $H^2 + H^1 \rightarrow He^3 + \nu$, followed by $He^3 + He^3 \rightarrow He^4 + H^1 + H^1$. The net result is the same as in the **carbon cycle,** namely, the synthesis of four hydrogen atoms into one helium atom, with the liberation of the mass difference as energy. It is thought that the proton-proton cycle is more important than the carbon cycle in the cooler stars, and that the reverse is true in the hotter stars. Both cycles are believed to be important in the sun.

PROXIMITY EFFECT. The change in current distribution (with the related changes in resistance and capacitance) in a conductor due to the field produced by an adjacent conductor.

PROXIMITY FUSE. Essentially a miniature **radar** transmitter-receiver, used in artillery shells, bombs, and rockets, which trips the firing mechanism when the armed device approaches within a predetermined distance of an object.

PSEUDO-ADIABATIC PROCESS. The process in which saturated air is rising in the atmosphere and is losing its water vapor by condensation and precipitation.

PSEUDO-CRYSTALS OR CRYSTALLITES. In many organic fibers, the structure consists of a number of small units, about 500 A long and 50 A in diameter (cellulose) arranged so that they all lie more or less parallel to the fiber axis. Each such crystallite consists of a nearly regular array of long chain polymers.

PSEUDOSCALAR. A **scalar** quantity which changes its sign when the coordinate system, to which the quantity is referred, is changed from a right-handed to a left-handed one, or vice versa. An example is the **scalar product** of a polar vector and a **pseudovector.**

PSEUDOSCALAR COUPLING. Type of **interaction energy** postulated between a π-meson and a nucleon which consists of the product of the **pseudoscalar field** of the π-meson and a bilinear pseudo-scalar function of the nucleon wave-functions.

PSEUDOSCALAR FIELD. A function of position and time which is unchanged by a **proper Lorentz transformation,** but which changes sign under an **improper Lorentz transformation.**

PSEUDOSCALAR PARTICLE. A particle, such as a π-meson, which may be described by a **pseudoscalar field.**

PSEUDOVECTOR. The **vector product** of two vectors does not completely satisfy the formal requirements of a **vector** for it changes sign if the coordinate system is changed from a right-handed to a left-handed one, or vice versa. It is a typical example of a pseudovector (also called an axial vector). Thus the vector for an element of area, represented by the vector product $d\mathbf{S} = d\mathbf{x} \times d\mathbf{y}$, is not determined with respect to direction unless an arbitrary convention is established for the positive side of the surface element. The three components of a pseudovector are actually the components of a three-dimensional antisymmetric **tensor** of second rank. Physical quantities which are pseudovectors include angular momentum (vector product of momentum and radius vector); moment of a force (vector product of force and distance); linear velocity (vector product of angular velocity and radius vector).

PSEUDOVECTOR COUPLING. Type of **interaction energy** postulated between a nucleon and other particles in which a bilinear pseudovector function of the nucleon wave-functions appears.

PSEUDOVECTOR FIELD. Four functions of position and time which transform like **a vector** under **proper Lorentz transformations** but which transform like a vector, together with a change of sign, under **improper Lorentz transformations.**

PSI. (1) Function of (ψ). (2) Time-dependent wave function (ψ). (3) Total electric flux (Ψ). (4) Planck function (Ψ). (5) Displacement flux (Ψ). (6) Azimuth angle or principle azimuth angle in optics (ψ).

PSI FUNCTION. (1) The name given by Gibbs to the function $\psi = U - TS$, where U is the **internal energy,** T, the absolute temperature, S, the entropy and ψ the psi function, which is discussed in this book under **free energy (2).** It is also known as the Helmholtz free energy, and is perhaps best known today as the work function. (2) A thermodynamic function, also known as the Massieu function, and defined by the equation

$$\psi = S - \frac{U}{T}$$

where S, U and T have the meanings given in (1) above. This is a less common usage than (1).

PSYCHROMETER. A combination of wet- and dry-bulb thermometers. A conventional sling psychrometer consists of two thermometers mounted parallel, with the wet bulb slightly lower than the dry. This instrument is whirled at approximately 3 m per sec for 3 or more minutes until the wet-bulb reading reaches a steady reading. The difference between dry- and wet-bulb reading is known as the wet-bulb depression and is correlated to other humidity criteria in tabular or graph form for instant use

PUBLIC ADDRESS SYSTEM. A sound reproducing apparatus for use in addressing large assemblages.

PULFRICH REFRACTOMETER. See **refractometer, Pulfrich.**

PULLING FIGURE. An indication of **oscillator stability** which is equal to the maximum change in frequency encountered when the load is changed so as to vary the voltage

standing-wave ratio of 1.5 through all phase angles.

PULSATANCE. See discussion of **alternating current.**

PULSE. (1) A variation of a quantity whose value is normally constant; this variation is characterized by a rise and decay, and has a finite duration. (2) A waveform whose duration is short compared to the time-scale of interest, and whose initial and final values are the same. The word "pulse" normally refers to a variation in time; when the variation is in some other dimension, it shall be so specified, such as "space pulse." This definition is broad so that it covers almost any transient phenomenon. The only features common to all pulses are rise, finite duration, and decay. It is necessary that the rise, duration, and decay be of a quantity that is constant (not necessarily zero) for some time before the pulse and has the same constant value for some time afterwards. The quantity has a normally constant value and is perturbed during the pulse. No relative time scale can be assigned.

PULSE AMPLIFIER. An **amplifier,** designed specifically to amplify the intermittent signals of a nuclear detector, incorporating appropriate pulse-shaping characteristics.

PULSE AMPLITUDE. A general term indicating the magnitude of a **pulse.** For specific designation, adjectives such as average, instantaneous, peak, rms (effective), etc., should be used to indicate the particular meaning intended. Pulse amplitude is measured with respect to the normally constant value, unless otherwise stated.

PULSE AMPLITUDE, AVERAGE. The **average** of the instantaneous amplitude taken over the **pulse duration.**

PULSE AMPLITUDE, AVERAGE ABSOLUTE. The **average** of the absolute value of the instantaneous amplitude taken over the **pulse duration.** By "absolute value" is meant the arithmetic value, regardless of algebraic sign.

PULSE-AMPLITUDE MODULATION OR PAM. See **modulation, pulse-amplitude or pam.**

PULSE AMPLITUDE, PEAK. The maximum absolute peak value of the **pulse,** excluding those portions considered to be unwanted, such as spikes. Where such exclusions are made, it is desirable that the amplitude chosen be illustrated pictorially.

PULSE AMPLITUDE, RMS (EFFECTIVE). The square root of the average of the square of the instantaneous amplitude, taken over the **pulse duration.**

PULSE BANDWIDTH. The smallest continuous frequency interval outside of which the amplitude of the spectrum does not exceed a prescribed fraction of the amplitude at a specified frequency. Caution—This definition permits the spectrum amplitude to be less than the prescribed amplitude within the interval. Unless otherwise stated, the specified frequency is that at which the spectrum has its maximum amplitude. This term should be "Pulse Spectrum Bandwidth" because it is the spectrum and not the pulse itself that has a bandwidth. However, usage has caused the contraction.

PULSE(S), BIDIRECTIONAL. **Pulses,** some of which rise in one direction and the remainder in the other direction

PULSE(S), BLANKING. In cathode ray tubes sharp rises in voltage that bias the viewing tube control grid beyond cut-off This action, when properly correlated with the brightness control, prevents the electron beam retraces from appearing on the viewing screen.

PULSE CARRIER. A **carrier** consisting of a series of **pulses.** Usually, pulse carriers are employed as **subcarriers.**

PULSE CARRIER, CREST FACTOR OF. The ratio of the peak pulse amplitude (see **pulse amplitude, peak**) to the root-mean-square amplitude. (See **pulse amplitude, rms.**)

PULSE, CARRIER FREQUENCY. A **carrier,** amplitude-modulated (see **modulation, amplitude**) by a **pulse.** The amplitude of the modulated carrier is zero before and after the pulse. **Coherence** of the carrier (with itself) is not implied.

PULSE CODE. (1) A **pulse train** modulated so as to represent **information.** (2) Loosely,

a **code** consisting of **pulses,** such as Morse code, Baudot code, binary code.

PULSE-CODE MODULATION (PCM). See **modulation, pulse-code (PCM).**

PULSE DECAY TIME. The interval between the instants at which the instantaneous amplitude last reaches specified upper and lower limits, namely, 90 per cent and 10 per cent of the peak-pulse amplitude (see **pulse amplitude, peak**) unless otherwise stated.

PULSE DELAY, RECEIVER. See **transducer pulse delay.**

PULSE DELAY, TRANSDUCER. See **transducer pulse delay.**

PULSE DROOP. A **distortion** of an otherwise essentially flat-topped rectangular **pulse,** characterized by a decline of the **pulse top.**

PULSE, DUNKING. Colloquialism for the recycling **pulse** employed in some amplitude selection circuits.

PULSE DURATION. (1) The time interval between the first and last instants at which the instantaneous amplitude reaches a stated fraction of the peak pulse amplitude. (See **pulse amplitude, peak.**) (2) The duration of a rectangular pulse whose energy and peak power equal those of the pulse in question. When determining the peak power, any **transients** of relatively short duration are frequently ignored.

PULSE-DURATION MODULATION OR PDM. See **modulation, pulse-duration or PDM.**

PULSE DUTY FACTOR. The ratio of the average **pulse duration** to the average **pulse spacing.** This is equivalent to the product of the average pulse duration and the **pulse repetition rate.**

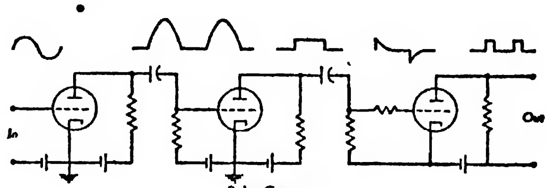
PULSE(S), EQUALIZING. Pulses at twice the line frequency, occurring just before and just after the vertical synchronizing pulses in television transmission. The equalizing pulses minimize the effect of line-frequency pulses on the **interlace.**

PULSE-FREQUENCY MODULATION. See **modulation, pulse-frequency.**

PULSE FREQUENCY SPECTRUM. See **pulse spectrum.**

PULSE, FRUIT. A pulse reply received as the result of interrogation of a **transponder** by interrogators not associated with the **responsor** in question.

PULSE GENERATOR. Many electronic devices or circuits utilize sharp pulses of current or voltage as a basic part of their operation. Such pulses must frequently be of very short time duration (microseconds) and accurately spaced in time. Others need not be repeated at regular time intervals but are initiated by some signal and are single narrow pulses each time a signal is received. The various types of circuits for generating these are termed pulse generators. As a simple illustration we might examine a basic pulse generating circuit as shown in the figure. The wave patterns



Pulse Generator

above the circuit diagram represent the wave form at the respective points in the circuit. A sine wave is applied to the **grid** of the first **tube,** which is biased so it clips the wave to the form shown applied to the second tube. This in turn clips the rounded top and gives the square wave shown at its output circuit. By passing this through a condenser-resistor circuit a series of triangular pulses is obtained. These pulses are applied through a grid resistor to the grid of a tube as shown. This tube levels them to produce a series of very narrow pulses spaced at the same intervals as the cycles of the original sine wave. The particular shapes shown in the diagrams are obtained by the proper choice of grid bias and condenser-resistor values in the coupling circuits. When the condenser has a low reactance compared to the resistance in series, the wave is passed without appreciable change of shape but, when the relative values are reversed, the wave form is materially changed as shown in the grid circuit of the final tube. While the circuit shown is relatively simple, it does illustrate some of the possibilities of shaping circuits.

PULSE HEIGHT ANALYZER. A device which records or counts a **pulse** only if the amplitude of the pulse falls within specified

limits (single channel) or within specified sets of limits (multi-channel). It thus yields the pulse height spectrum of a group of pulses. In many applications this gives the energy spectrum of nuclear radiations.

PULSE HEIGHT DISCRIMINATOR. A circuit designed to select and pass voltage **pulses** of a certain minimum amplitude.

PULSE HEIGHT DISCRIMINATOR, DIFFERENTIAL. A **pulse height selector.**

PULSE HEIGHT SELECTOR. A circuit designed to select and pass voltage **pulses** in a certain range of amplitudes.

PULSE INTERLEAVING. A process in which **pulses** from two or more sources are combined in time-division **multiplex** for transmission over a common path.

PULSE INTERROGATION. The **triggering** of a **transponder** by a **pulse** or **pulse mode.**

PULSE INTERVAL. See **pulse spacing.**

PULSE-INTERVAL MODULATION. A form of **pulse-time modulation** in which the **pulse spacing** is varied.

PULSE LEADING EDGE. The major portion of the rise of a **pulse.**

PULSE JITTER. A relatively small variation of the **pulse** spacing in a **pulse train.** The jitter may be random or systematic, depending on its origin, and is generally not coherent with any pulse modulation imposed.

PULSE-LENGTH MODULATION. See **pulse-duration modulation.**

PULSE MODE. (1) A finite sequence of **pulses** in a prearranged pattern, used for selecting and isolating a communication channel. (2) The prearranged pattern.

PULSE-MODE MULTIPLEX. A process or device for selecting channels by means of **pulse modes.** This process permits two or more channels to use the same **carrier frequency.**

PULSE MODE, SPURIOUS. An unwanted **pulse mode,** formed by the chance combination of two or more pulse modes, which is indistinguishable from a **pulse interrogation** or **pulse reply.**

PULSE MODULATION. See **modulation, pulse.**

PULSE MODULATOR. See **modulator, pulse.**

PULSE PHASE MODULATION (PPM). See **modulation, pulse position.**

PULSE-POSITION MODULATION OR PPM. See **modulation, pulse-position.**

PULSE POWER, CARRIER-FREQUENCY, PEAK. See **peak pulse power, carrier-frequency.**

PULSE POWER, PEAK. See **peak pulse power.**

PULSE, RADIO-FREQUENCY. A radio-frequency **carrier,** amplitude-modulated by a **pulse.** The amplitude of the modulated carrier is zero before and after the pulse. Coherence of the carrier (with itself) is not implied.

PULSE REGENERATION. The process of restoring **pulses** to their original relative timings, forms, and/or magnitudes. In many devices, pulses may become distorted due to phase or amplitude distortion, limiting, or other processes. It is often desirable to restore the pulse to something resembling its original form before it has become so distorted that the original information which it contains is completely destroyed. This process is normally called pulse regeneration.

PULSE REPEATER (TRANSPONDER). A device used for receiving **pulses** from one circuit and transmitting corresponding pulses into another circuit. It may also change the frequency and waveforms of the pulses, and perform other functions.

PULSE REPETITION FREQUENCY. The **pulse repetition rate** of a periodic **pulse train.**

PULSE REPETITION PERIOD. The reciprocal of the **pulse repetition frequency.**

PULSE REPETITION RATE. The average number of **pulses** per unit of time.

PULSE REPLY. The transmission of a **pulse** or **pulse mode** by a **transponder** as the result of an **interrogation.**

PULSE RISE TIME. The interval between the instants at which the instantaneous amplitude first reaches specified lower and upper

limits, namely, 10 per cent and 90 per cent of the peak-pulse amplitude (see **pulse amplitude, peak**), unless otherwise stated.

PULSE SEPARATION. The interval between the trailing-edge **pulse-time** of one **pulse** and the leading-edge pulse-time of the succeeding pulse.

PULSE, SERRATED. In television the vertical synchronizing signal, which is divided into six equal pulses which are preceded and succeeded by six equalizing pulses. (See **television, synchronizing signal.**)

PULSE SHAPER. A **transducer** used for changing one or more characteristics of a **pulse.** This term includes **pulse regenerators.**

PULSE SHAPING. Intentionally changing the shape of a **pulse.**

PULSE SPACING (PULSE INTERVAL). The interval between the corresponding **pulse times** of two consecutive **pulses.** The term "pulse interval" is deprecated because it may be taken to mean the duration of the pulse instead of the space or interval from one pulse to the next. Neither term means the space between pulses

PULSE SPECTRUM (PULSE FREQUENCY SPECTRUM). The frequency distribution of the sinusoidal components of the **pulse** in relative amplitude and in relative phase. The definition of this term is phrased to convey the idea that the spectrum is a complex (phasor) function of frequency, and to express this function most nearly in a manner which corresponds to the method of measuring it (i.e., measuring amplitude and phase separately).

PULSE SPIKE. An unwanted **pulse** of relatively short duration superimposed on the main pulse. This term came into wide use in **radar** to define the first part of the pulse fed through a **TR tube.** This portion contains most of the pulse energy, has a duration about 10^{-3} that of the rest of the pulse, and an amplitude up to 10^6 to 10^9 times that of the rest of the pulse. Seen on a cathode-ray tube, it looks like a spike sticking up from the pulse. By extension, the term has come to be applied to any unwanted pulse of relatively short duration, superimposed on the wanted pulse.

PULSE SPIKE AMPLITUDE. The **peak pulse amplitude** of the **pulse spike.**

PULSE STRETCHER. A device for increasing the duration of a pulse with little or no change in its other characteristics.

PULSE TILT. A **distortion** in an otherwise essentially flat-topped rectangular **pulse,** characterized by either a decline or a rise of the **pulse top.**

PULSE TIME, LEADING-EDGE. The time at which the instantaneous amplitude first reaches a stated fraction of the peak pulse amplitude. (See **pulse amplitude, peak.**)

PULSE TIME, MEAN. The arithmetic mean of the leading edge **pulse time** and the trailing edge pulse time. For some purposes the importance of a **pulse** is that it exists (or is large enough) at a particular instant of time. For such applications the important quantity is the mean pulse time. The leading edge pulse time and trailing edge pulse time are significant primarily in that they may allow a certain tolerance in timing.

PULSE-TIME MODULATION. Modulation in which the time of occurrence of some characteristic of a **pulse carrier** is varied from the unmodulated value This is a general term which includes several forms of modulation, such as **pulse-duration, pulse-position, pulse-interval modulation.**

PULSE TIME, TRAILING-EDGE. The time at which the instantaneous amplitude last reaches a stated fraction of the peak pulse amplitude. (See **pulse-amplitude, peak.**)

PULSE TRAIN. A sequence of **pulses.**

PULSE TRAIN, BIDIRECTIONAL. A **pulse train,** some **pulses** of which rise in one direction and the remainder in the other direction.

PULSE TRAIN, PERIODIC. A **pulse train** made up of identical groups of **pulses,** the groups repeating at regular intervals.

PULSE-TRAIN SPECTRUM (PULSE-TRAIN FREQUENCY-SPECTRUM). The frequency distribution of the sinusoidal components of the **pulse-train** in amplitude and in phase angle.

PULSE TRAIN, UNIDIRECTIONAL. A **pulse train** in which all **pulses** rise in the same direction. A unidirectional pulse.

PULSE TRANSMITTER. See **transmitter, pulse.**

PULSE, UNIDIRECTIONAL. A pulse in which pertinent departures from the normally constant value occur in one direction only. This is sometimes called "single-polarity" pulse, a term which is deprecated.

PULSE VALLEY. The part of the **pulse** between two specified maxima. Unless otherwise specified, it is to be understood that the maxima are the first and the last.

PULSE WIDTH. A deprecated usage. (See **pulse duration.**)

PULSE-WIDTH MODULATION. See **pulse-duration modulation.**

PULSED OSCILLATOR. See **oscillator, pulsed.**

PULSED-OSCILLATOR STARTING TIME. The interval between the leading-edge **pulse-time** of the **pulse** at the oscillator control terminals, and the leading-edge pulse-time of the related output pulse.

PULSERS IN MICROWAVES. The generator of an essentially-rectangular current pulse to power a pulsed **microwave oscillator.** They are of two varieties, the first of which is the vacuum-tube (hard-tube) pulser which discharges a capacitor through the load. The second is the line-type pulser which charges an open-ended **transmission line** through a high impedance, and discharges it through the load.

PULSING METHOD OF MEASURING VELOCITIES IN LIQUIDS. The velocity and attenuation for longitudinal waves in liquids is measured by transmitting short acoustic pulses through the liquid The time of transmission can be compared with that for a radio signal to cover the same distance.

PUMP, OIL-VAPOR. A **diffusion pump** which uses a low vapor-pressure oil as its working fluid.

PUMP, SELF-FRACTIONATING. An oil **diffusion pump** which incorporates a fractionating device which provides for the segregation of the more volatile constituents of the oil into regions where they will do no harm, and also isolates the non-volatile tarry residues formed by chemical association of the products of cracking with the original oil molecules or with one another.

PUMP, VACUUM, BACKING. A pump designed to produce a rough fore-vacuum (of the order of a fraction of an atmosphere) into which a high-vacuum pump can work.

PUMP, VACUUM FORE. A backing vacuum pump which maintains a low enough pressure so that a **diffusion pump** can operate into it. Modern forepumps produce pressure down to about 0.001 mm of mercury.

PUMP, VACUUM, GAEDE ROTARY OIL. A pump consisting of a steel cylinder, traversed by a diametral slot, rotating about its axis, which is set eccentrically in a cylindrical steel casing so that the cylinder is in contact with the casing along the top. Two vanes, working in the slot, are pushed apart by a spring, and slide against the casing as the cylinder rotates. Inlet and outlet ports are provided, one on either side of the line of contact of cylinder and casing The whole mechanism is immersed in an oil bath with the opening of the outlet part below the surface of the oil As the cylinder rotates gas is sucked in from the inlet port and swept along and rejected into the outlet port The oil serves as a lubricant and to seal dead spaces.

PUMP, VACUUM, MOLECULAR. A pump consisting of a drum which rotates at high speed within a cylindrical casing, arranged so that the clearance between them around part of the circumference is exceedingly small. The rotation of the drum imparts to the molecules colliding with it a drift in the direction of rotation, thus the equilibrium pressures at the ends of the tighter-fitting section of the casing are different.

PUMP, VACUUM, PUMPING SPEED OF. The volume of gas extracted by a pump in unit time, measured at the mean pressure prevailing in the vacuum vessel during that time.

PUMP, VACUUM, TAEPLER MERCURY. A pump whose operation depends on first producing a Torricellian vacuum above a column of mercury, allowing this to communicate with the vessel to be evacuated, and finally sweeping the gas away with mercury, this cycle of operations being repeated again and again.

PUMP, VACUUM, WATER-JET (ASPIRATOR). A pump consisting of an enclosed nozzle through which a jet of water flows. The jet entrains air molecules in the enclosing chamber, thus reducing the pressure in the chamber.

PUPIN COIL. Another name for a **loading coil.**

PURE TONE. See **tone, simple.**

PURITY (COLOR). See **purity (excitation purity).**

PURITY (EXCITATION PURITY). The ratio of the distance from the reference point to the point representing the sample, to the distance along the same straight line from the reference point to the **spectrum locus** or to the purple boundary, both distances being measured (in the same direction from the reference point) on the CIE **chromaticity diagram.** The reference point is the point in the chromaticity diagram which represents the reference standard light mentioned in the definition of **dominant wavelength.**

PURITY, COLORIMETRIC. The ratio of the **luminance** of a spectrally-homogeneous component to the luminance of the white (achromatic) light with which it must be mixed, in order to match the **chromaticity** of a sample of light.

PURITY, SPECTRAL. As applied to radiant energy, the property of having a single wavelength

PURKINJE EFFECT. With a good level of illumination, the spectral sensitivity of the normal eye is greatest in the yellow-green region. As the illumination is reduced, the maximum sensitivity shifts toward the blue. This shift is called the Purkinje effect.

PURPLE BOUNDARY. The straight line drawn between the ends of the spectrum locus. (See figure in definition of **chromaticity diagram.**)

PUSHBUTTON TUNING. A semi-automatic method of tuning a radio **receiver** to any one of several preselected stations. The usual types may be divided into two classes, mechanical and electrical. The first is simply a mechanical linkage between the pushbutton on the panel and the tuning condenser or coil in the set. To set this type the linkage is adjusted to vary the tuning just the right amount to set the receiver to the desired station. In the more refined electrical system each button switches in a fixed tuning unit which has been pre-set to the desired frequency. Since these frequencies can be very accurately set and require no mechanical linkages, the results are more satisfactory than the mechanical type. In either type, however, the various buttons and associated circuits or mechanisms are pre-adjusted for various commonly desired stations and then by pushing the proper button the station is tuned in.

"PUSH-PULL" ENERGIZATION. A term used in electronics to describe a symmetrical **excitation** supplied to a **network** having mirror symmetry about a neutral, or grounded, point. High-power **audio amplifiers** are often arranged in a symmetrical push-pull arrangement, with two tubes "driving" a center-tapped transformer primary. The symmetry produces cancellation of even-order harmonics, primarily the second harmonic. (See also **amplifier, balanced.**)

PUSH-PULL MICROPHONE. A **microphone** consisting of two identical elements coupled to either side of the same diaphragm and electrically connected 180° out of phase. The double-button carbon microphone is an example.

PUSH-PULL OSCILLATOR. See **oscillator, push-pull.**

PUSH-PUSH CIRCUIT. A circuit employing two similar tubes with grids connected in phase opposition and plates in parallel to a common load, and usually used as a **frequency multiplier** to emphasize even-order harmonics.

PUSH-PUSH CURRENTS. Currents flowing in the two conductors of a **balanced line** which, at every point along the line, are equal in magnitude and in the same direction.

PUSH-PUSH VOLTAGES. Voltages (relative to ground) on the two conductors of a **balanced line** which, at every point along the line, are equal in magnitude and have the same polarity.

PUSHING FIGURE. The difference between the values of oscillator frequency measured at specific values of direct electrode current frequency changes caused by thermal effects being excluded. A measure of the dependence

of oscillator frequency upon electrode currents.

PYCNOMETER. A device for measuring densities of liquids. It is a container of accurately-known capacity that can be completely filled with the liquid. The mass of liquid is then determined by weighing. A familiar design is the "specific gravity bottle."

PYRAMID. A **polyhedron** with a **polygon** on one face and with triangles as the other faces, these meeting in a common vertex.

PYRAMIDAL HORN. See **horn, pyramidal.**

PYRANOL. Trade name for an Askarel (chlorinated synthetic) impregnant for paper **capacitors.**

PYRANOMETER. An instrument measuring radiation from sun or sky by its heating action upon two blackened metallic strips, as compared with the electric current which produces the same heating effect. Commonly the two blackened strips differ greatly in thickness, and hence the temperature rise on exposure to radiation is less in the thick strip than in the thin one.

PYRGEOMETER. An instrument measuring radiation from the earth's surface into space. It has both blackened and polished areas; the former cool more rapidly by radiation from them, and the heating electric current necessary to prevent this differential cooling measures the amount of radiation.

PYRHELIOMETER. An instrument for measuring the total intensity of solar radiation, both direct and scattered by the atmosphere.

PYROMETER. In earlier usage a pyrometer was a device for measuring high temperatures, but these instruments are now used also for temperatures in the same range as thermometers, and below the thermometric range. Four major types of pyrometer are the **thermoelectric pyrometer** (thermel or thermocouple), the **resistance pyrometer,** the **optical pyrometer** and the (total) **radiation pyrometer.**

PYROMETRIC CONES. Small cones that differ in the temperatures at which they soften on heating. They are made of clay and other ceramic materials and are used in the ceramic industries to show furnace temperatures within ranges. In practice, three or four of the cones which have softening points at consecutive temperature ranges are used, and the increase in kiln temperature is judged from the progressive deformation of the cones.

PYROMETRY. The art of measuring high temperatures.

PYRON DETECTOR. A form of crystal detector employing iron pyrites

PYTHAGOREAN SCALE. A musical **scale** such that the frequency intervals are represented by the ratios of integral powers of the numbers 2 and 3.

Q

Q. (1) A **figure of merit** of an energy-storing system equal to

$$2\pi\left(\frac{\text{average energy stored}}{\text{energy dissipated per half cycle}}\right),$$

which is equal to $\omega L/R$ for an inductor, where R is the equivalent series resistance. For a capacitor, Q is $1/\omega CR$, again the ratio of reactance to effective resistance. For a medium, Q is the ratio of **displacement current density** to **conduction current density.** The basic equation may also be expanded to include series and parallel resonant circuits, for which cases appropriate approximate equations may also be developed (see **sharpness of resonance**). (2) Quantity of heat, light, or energy (Q). (3) Electric charge (Q or q). (4) Heat entering system (q). (5) Moment of area (Q). (6) Electric quadrupole moment of atomic nucleus (Q). (7) Thermoelectric power (Q).

Q-BRANCH. See **Fortrat parabola.**

Q, DECREMENT MEASUREMENT OF. The measurement of the **Q** of resonant systems by observing the rate of decay of energy stored. The equation for Q may be expressed as

$$e^{-\frac{\omega}{Q}(t-t_0)} = \frac{\text{energy at time } t}{\text{energy at time } t_0}$$

where ω is the frequency of oscillation, and zero energy is added between t_0 and t.

Q DETERMINATION BY VSWR MEASUREMENT. Q is equal to twice the reciprocal of the percentage change in the frequency applied to a resonant circuit required to change its power to 50% of that at **resonance.** In microwave systems this change in power is most easily determined by VSWR (voltage standing wave ratio) measurements. This relationship is only approximate for values of Q below ten.

Q-ELECTRON. An **electron** having an **orbit** of such dimensions that the electron constitutes part of the seventh shell (or **Q-shell**) of electrons surrounding the atomic nucleus, counting out from the nucleus (i.e., the K-shell is the first; the L-, the second; the M-, the third; the N-, the fourth; the O-, the fifth; the P-, the sixth; and the Q-, the seventh).

Q MEASUREMENT BY TRANSMISSION (BANDWIDTH) (IMPEDANCE). **Q** is equal to twice the reciprocal of the percentage change in the frequency applied to a resonant circuit required to change its **impedance** to a value different from its resonant impedance by a factor of $\sqrt{2}$. This relationship is only approximate, but is quite accurate for values of Q in excess of ten.

Q OF A CIRCUIT, LOADED. When two circuits are **coupled** tightly together, or one is "loaded" by the other, the resultant **Q** will equal the reciprocal of the sum of the reciprocals of the two original Q's.

Q OF A CIRCUIT, UNLOADED OR INTRINSIC. The basic **Q** of the circuit by itself.

Q-NUMBER THEORY. Second quantized **field theory** in which wave functions are replaced by operators which in general do not commute. (See **second quantization.**)

Q-SHELL. The seventh layer of electrons in motion about the nucleus of an atom; the first, or innermost, layer being the K-shell; the second, the L-shell; the third, the M-shell; the fourth, the N-shell; the fifth, the O-shell; and the sixth, the P-shell. The Q-shell is started, it is believed, with the element **francium** (atomic number = 87) and the elements of higher atomic number have electrons in Q-shells.

Q SIGNAL. A set of three-letter symbols beginning with the letter Q which serve as abbreviated messages as standardized by the International List of Abbreviations for Telegraphy.

Q-VALUE. A synonym for **disintegration energy, nuclear.**

QUADRANT ELECTROMETER. Discussed under **electrometer.**

QUADRATIC EQUATION IN TWO VARIABLES. Its general form is $Ax^2 + Bxy + Cy^2 + Dx + Ey + F = 0$ and its curve is a **conic section.** The nature of the curve is determined by **invariants** of the equation, I and the **discriminant,** Δ.

$$I = (B^2 - 4AC);$$

$$\Delta = \frac{1}{2}\begin{vmatrix} 2A & B & D \\ B & 2C & E \\ D & E & 2F \end{vmatrix}.$$

The possible cases are

I	Δ	Nature of Curve
0	$A\Delta < 0$	ellipse; circle if $B = 0$, $A = C$
	$A\Delta > 0$	imaginary locus
	0	a point
>0	$\neq 0$	hyperbola
	0	two intersecting straight lines
<0	$\neq 0$	parabola
	0	$A \neq 0$; $H = D^2 - 4AF = 0$, one line;
		$H > 0$, two parallel lines;
		$H < 0$, imaginary locus
		$A = 0$; $J = E^2 - 4CF = 0$, one line;
		$J > 0$, two parallel lines;
		$J < 0$, imaginary locus

QUADRATIC FORMULA. The roots of the quadratic equation in one variable, $ax^2 + bx + c = 0$ are given by this formula, which is

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}.$$

Its **discriminant,** $D = b^2 - 4ac$. If $D > 0$, the roots of the equation are real and unequal; if $D = 0$, they are real and equal; if $D < 0$, both roots are imaginary.

QUADRATRON. A high-vacuum **tetrode.**

QUADRATURE. Given a differential equation of the form $F(x,y,y' = dy/dx) = 0$, it is reduced to quadrature if it may be written

$$y = \int f(x)\, dx.$$

When the integral cannot be evaluated in terms of known functions, numerical, graphical, or mechanical methods may be used. These are known as approximate or mechanical quadratures. (See **numerical integration.**)

QUADRIC, CENTRAL. A special case of a **quadric surface** represented by the equation

$$Ax^2 + By^2 + Cz^2 = 1;$$

thus the surface is symmetric about the coordinate origin It could be an **ellipsoid** or a **hyperboloid.** The other quadric surfaces: a **paraboloid** and the degenerate quadrics (see **quadric surface**) are non-central quadrics.

QUADRIC, CONFOCAL. A system of three **quadric surfaces** having the same foci. Sections of these surfaces through their axes are confocal conics. The quadrics composing the system are represented by the equation

$$\frac{x^2}{A - q} + \frac{y^2}{B - q} + \frac{z^2}{C - q} = 1$$

where $A > B > C$ and q is a variable parameter. When q is negative or less than C, the surface is an **ellipsoid;** if $B > q > C$, a **hyperboloid of one sheet;** if $A > q > B$, a **hyperboloid of two sheets;** if $q > A$, the quadric is imaginary. The three surfaces are mutually orthogonal and are used as a **curvilinear system** called **ellipsoidal coordinates.** If two of the constants A, B, C become equal, quadrics of revolution result; if all three are equal, the quadric is a **sphere.**

QUADRIC, DEGENERATE. See **quadric surface.**

QUADRIC SURFACE. Any of the surfaces represented in Cartesian coordinates by an algebraic equation of the second degree in three variables

$$Ax^2 + By^2 + Cz^2 + 2Fyz + 2Gxz + 2Hxy + 2Px + 2Qy + 2Rz + D = 0.$$

Special cases, determined by **relations** between the constants A, B, $\cdots$ are **ellipsoids, hyperboloids, paraboloids** and the **degenerate quadrics:** conical and cylindrical sur-

faces, lines, or points. (Also called a **conicoid.**)

QUADRUPLE POINT. The temperature at which four **phases** are in **equilibrium.** An example is the case in which an anhydrous salt, a hydrate of the salt, its saturated solution, and its water vapor are in equilibrium in a salt-water system.

QUADRUPLE PRODUCT OF VECTORS. If **A**, **B**, **C**, **D** are any four vectors, two types of **products** are possible:

(1) $(\mathbf{A} \times \mathbf{B})\cdot(\mathbf{C} \times \mathbf{D}) = (\mathbf{A}\cdot\mathbf{C})(\mathbf{B}\cdot\mathbf{D}) - (\mathbf{A}\cdot\mathbf{D})(\mathbf{B}\cdot\mathbf{C});$

(2) $(\mathbf{A} \times \mathbf{B}) \times (\mathbf{C} \times \mathbf{D}) = (\mathbf{A}\cdot\mathbf{C} \times \mathbf{D})\mathbf{B} - (\mathbf{B}\cdot\mathbf{C} \times \mathbf{D})\mathbf{A}.$

The latter equation is also conveniently written in the equivalent form

$$[\mathbf{ACD}]\mathbf{B} - [\mathbf{BCD}]\mathbf{A} = [\mathbf{ABD}]\mathbf{C} - [\mathbf{ABC}]\mathbf{D},$$

where the bracket signifies the scalar **triple product.** (See also **vector system, reciprocal.**)

QUADRUPOLE. Let a collection of electric or magnetic charges be distributed around a point; for example, the center of mass of a system of atoms, molecules, or nuclei. The potential at a distance r from this point may be represented by an infinite series of terms in inverse powers of r. The term in the inverse first power is the **Coulomb potential,** the inverse second power term is the **dipole potential,** the inverse third power term is the quadrupole potential, etc. A typical example is an array of four charges of equal magnitude so spaced that they coincide with the vertices of a parallelogram. Charges located on opposite vertices are of the same sign; the distance of separation between charges is taken to be of the order of molecular or infinitesimal dimensions.

QUADRUPOLE MOMENT. When the radiation field due to a set of moving electric or magnetic charges is expanded in a series of powers of the product of the charges times space coordinates, the sum of the quadratic terms is the quadrupole moment.

QUADRUPOLE RADIATION. Radiation emitted by a **quadrupole.** Since the selection rules were deduced by analogy between the behavior of a classical electric dipole and the emission of radiation by quantum transitions, then there are arrangements of two dipoles (e.g., a linear arrangement in which the positive charges coincide and are located at the center of two negative charges separated by a distance $2x$ (x = distance from center), so $\Sigma e_i x_i = 0$) when the quadrupole moment ($\Sigma e_i \cdot x_i^2$) not zero but varies as $1/r^3$, and therefore acts as a source of radiation.

QUANTIC. A **homogeneous algebraic function** of two or more variables, in general containing only positive integral powers of the variables, and usually a polynomial in several variables. Quantics are classified into quadratic, cubic, quartic, quintic, etc., according to degree, and into binary, ternary, quaternary, etc., according to the number of variables involved. (See also **multinomial.**)

QUANTITY OF RADIATION. The time integral of intensity of radiation; it is the total energy which has passed through unit area perpendicular to the beam and is expressed in ergs per cm^2 or watt-seconds per cm^2.

QUANTIZATION. An observable quantity is said to be quantized when its magnitude is, in some or all of its range, restricted to a discrete set of values. If the magnitude of the quantity is always a multiple of a definite unit, then that unit is called the **quantum** (of the quantity).

QUANTIZATION DISTORTION (QUANTIZATION NOISE). Inherent **distortion** introduced in process of **quantization (of signal levels).**

QUANTIZATION LEVEL. In **quantization (of signals)** a particular sub-range, or a symbol designating it

QUANTIZATION NOISE. See **quantization distortion.**

QUANTIZATION OF SIGNALS. A process in which the range of values of a wave is divided into a finite number of smaller subranges, each of which is represented by an assigned or "quantized" value within the subrange. "Quantized" may be used as an adjective modifying various forms of modulation, for example, quantized **pulse-amplitude modulation.**

QUANTIZATION, SECOND. See **second quantization.**

QUANTIZE. To restrict the possible values of a variable to a discrete number of possible values.

QUANTIZED FIELD THEORY. See **field theory, quantized.**

QUANTIZED PULSE MODULATION. Pulse modulation which involves **quantization.** This is a generic term, including pulse-numbers modulation and pulse-code modulation as specific cases.

QUANTUM. As stated under **quantization,** an observable quantity is said to be quantized when its magnitude is, in some or all of its range, restricted to a discrete set of values. If the magnitude of the quantity is always a multiple of a definite unit, then that unit is called the quantum (of the quantity). For example, the quantum or unit of orbital angular momentum is $\hbar$, and the quantum of energy of electromagnetic radiation of frequency ν is $h\nu$. In field theories, a field (or the field equations) is quantized by application of a proper quantum-mechanical procedure and this results in the existence of a fundamental field particle, which may be called the field quantum. Thus the **photon** is a quantum of the electromagnetic field and in nuclear field theories, the **meson** is considered to be the quantum of the nuclear field.

QUANTUM EFFICIENCY. A measure of the efficiency of conversion or utilization of light or other energy, being in general the ratio of the number of distinct events produced in a radiation sensitized process to the number of quanta absorbed (the intensity-distribution of the radiation in frequency or wavelength should be specified). In the **photoelectric** and **photoconductive effects,** the quantum efficiency is the number of electronic charges released for each **photon** absorbed. For a **phototube,** the quantum efficiency is defined as the average number of electrons photometrically emitted from the **photocathode** per incident photon of a given wavelength. In a photochemical reaction, the quantum efficiency is the ratio of the number of molecules transformed to the number of quanta of radiation absorbed.

QUANTUM ELECTRODYNAMICS. Quantized field theory of the interaction between electrons, positrons and radiation based on the quantized form of the **Maxwell equations** and the **Dirac electron theory.** The theory is characterized by its remarkably accurate predictions (see **radiative corrections; positronium**) and its meaningless results. The latter arise from divergent integrals which appear in the development of the theory by perturbation techniques based on expansion in powers of the **fine structure constant** (see **vacuum polarization; self-energy**). These divergences may be pictured in terms of the model of a vacuum as consisting of an infinite sea of negative energy electrons, since the introduction of a charge into this distribution causes infinite currents to be induced.

In 1948, techniques introduced by Schwinger and Feynman enabled these difficulties to be avoided, without being removed. Their relativistically covariant development of the theory allowed such infinite terms to be treated unambiguously, and in particular terms which are to be understood as electrodynamic contributions to the charge and mass of a particle were put in a form which is invariant under **Lorentz transformations.** The program of **charge renormalization** and **renormalization of mass** then enabled such terms to be related to the experimentally observed charge and mass of the particle. (See **Feynman diagram.**)

QUANTUM MECHANICS (NON-RELATIVISTIC). Theory of the motion of a dynamical system valid, as far as is known, provided that there exists an observer for whom the momenta of the particles of the system are small compared with c times their mass. The quantum theory of the motion of a particle does not depart significantly from the classical theory, however, unless the fractional change in the momentum p over a distance of the order of the **de Broglie wavelength** $\lambda = h/p$ is greater than, or of the order of, unity. Quantum mechanics developed from the inadequacy of classical mechanics to describe **black-body radiation,** the **photoelectric effect** and **atomic spectra** without the addition of extra hypotheses postulated by Planck, Einstein, and Bohr and Sommerfeld, respectively, and from the inability of the theory, even supplemented by these hypotheses, to yield complete agreement with experiment (as, for example, the spectrum of helium).

Quantum mechanics was initiated in 1923 by de Broglie who postulated that a wave of

wavelength λ given above accompanies an electron and showed that the Bohr-Sommerfeld conditions for periodic motion around a closed path follow from the condition that this phase wave be tuned to the length of the path. In the following year the idea of a wave accompanying the motion of a particle was shown by Einstein to arise from the application of **Einstein-Bose statistics** to an ensemble of indistinguishable particles in the same way that the application of these statistics to electromagnetic radiation yielded the **Planck radiation law** already known to reveal both the wave and particle nature of such radiation. In 1926 the **Schrödinger equation** described the motion of the de Broglie phase waves under the influence of an externally applied potential, and the physical significance of the phase wave ψ was recognized particularly by Born by identifying $\psi^*(q_k)\psi(q_k)d\tau$ with the probability of finding the system in the element of configuration space $d\tau$ between q_1 and $q_1 + dq_1$, etc. Independently in 1925 Heisenberg developed a calculus of observable quantities, representing dynamical variables such as momentum, position, etc, by means of matrices, the time rate of change of a variable X being given by $i\hbar\dot{X} = XH - HX$ where H is the **Hamiltonian** of the system. This formulation (matrix mechanics) of quantum theory is equivalent to the Schrödinger formulation (wave mechanics) but emphasizes the role played by the observer in the measurement of a physical quantity and the fact that natural limits imposed on measurements which he makes must be incorporated into a theory which purports to describe such measurements. Thus in particular to specify the momentum p and corresponding position x of a particle is strictly speaking not legitimate since the very measurement of the one will lead to an unpredictability of the other given by the Heisenberg **indeterminancy relation** $\Delta x \Delta p \sim \hbar$. Dynamical variables which cannot be measured simultaneously with arbitrary precision are thus represented by matrices, or, more generally, operators, which may not commute, while a system in the state ψ has a definite value for the dynamical variable A if ψ is an **eigenfunction** of the operator A, i.e., $A\psi = a\psi$ (a = number). Thus if A and B do not commute ψ cannot be at once an eigenfunction of both A and B. A system in an eigenstate of energy is thus described by the equation $H\psi = E\psi$ where H is the Hamiltonian of the system. In the **Schrödinger representation** (wave mechanics) ψ is regarded as a function of position and time and the momentum p appearing in the Hamiltonian is represented by the operator $-i\hbar$ grad, which automatically yields the **commutation relation** $p_i x_j - x_j p_i = -i\hbar\delta_{ij}$. In the **Heisenberg representation** (matrix mechanics) the position and momentum are represented by matrices which satisfy this commutation relation, and ψ by a constant vector in **Hilbert space,** the eigenvalues E being the same in the two cases.

The Hamiltonian of a particular system is formally identical with that of the classical theory, the simplest, for one particle of mass m moving in a potential V, being

$$H = \frac{p^2}{2m} + V = E,$$

which in the Schrödinger representation gives the **Schrödinger equation**

$$\left(-\frac{\hbar^2}{2m}\nabla^2 + V\right)\psi = E\psi.$$

In the presence of a magnetic field B derived from the **vector potential A** it is necessary to replace

$$\mathbf{p} = -i\hbar\nabla$$

by

$$\mathbf{p} - \frac{e}{c}\mathbf{A} = -i\hbar\left[\nabla - \frac{ie}{\hbar c}\mathbf{A}\right]$$

and in addition to note the contribution $-\mu\cdot B$ to the energy arising from the magnetic moment $\boldsymbol{\mu}$ of the particle. The vector $\boldsymbol{\mu}$ is itself an operator, being, for an electron, $(e/mc)\mathbf{S}$ where $\mathbf{S}$ is the electron spin $\mathbf{S} = (\hbar/2)\boldsymbol{\sigma}$, the components of $\boldsymbol{\sigma}$ being the Pauli spin operators. The value e/mc for the electron **gyromagnetic ratio** was first postulated by Uhlenbeck and Goudsmit and later shown to be a consequence of the **Dirac electron theory.** (It also follows from classical special relativity theory (see **relativity theory, special**) under suitable assumptions.)

Non-relativistic quantum mechanics, extended by the theory of electron spin and by the **Pauli exclusion principle,** provides a reliable theory for the computation of atomic spectral frequencies and intensities, of cross sections for scattering or capture of electrons by atomic systems, of chemical bonds and

many properties of solids, including magnetic properties, although with such more complicated systems it has not always proved possible to develop with adequate accuracy the consequences of the theory. Quantum mechanics has also had a limited success in nuclear theory although in this field it is possible that a more fundamental system of mechanics is required.

QUANTUM MECHANICS (RELATIVISTIC). Generalization of non-relativistic quantum mechanics in which the quantum equations of motion satisfy the principle of relativity (see **relativity theory, special**). In its simplest form the equation of motion of a particle is the **Klein-Gordon equation,** but since this neglects the spin properties of the particle the best verified form of relativistic quantum mechanics is provided by the **Dirac electron theory.** In general the relativistic quantum theory of a system may always be derived (as far as is known) from a **Lagrangian,** the relativistically covariant properties of the resulting equations of motion being automatically assured if the Lagrangian is invariant under **Lorentz transformations.** (See also **field theory; quantum electrodynamics.**)

QUANTUM NUMBER. A number assigned to one of the various values of a quantized quantity in its discrete range The **quantum** numbers arise from the mathematics of the eigenvalue problem and may be related to the number of **nodes** in the **eigenfunction.** When the quantity has a quantum, the quantum number is the number of such quantums. A state may be described by giving a sufficient set of compatible quantum numbers In the customary formulations, each quantum number is either an integer (which may be positive, negative or zero) or an odd half-integer. For example, for a nucleus the quantum numbers of most interest are the total angular momentum quantum number (called the **nuclear spin quantum number**) and the **parity.** (See **angular momentum; atomic and nuclear physics.**)

QUANTUM NUMBER, AZIMUTHAL. (Obs.) A quantum number characterizing the angular momentum of an electron in the Bohr model of the atom. It was related to the ellipticity of the electronic orbit about the nucleus.

QUANTUM NUMBER, INNER. A term sometimes applied to the sum of the azimuthal quantum number and the spin quantum number, representing the resultant of the two corresponding contributions to the angular momentum of the electron.

QUANTUM NUMBER, ISOBARIC SPIN. A nuclear **quantum number** based upon the concept that the proton and the neutron are different states of the same elementary particle, the nucleon. The nucleon is assigned an isobaric spin quantum number of $\frac{1}{2}$, and its two possible orientations, $\tau_Z = +\frac{1}{2}$ and $-\frac{1}{2}$, are assigned to the neutron and proton, respectively. The isobaric spin vectors of all nucleons in a given nucleus combine as do angular momentum vectors, to give a total isobaric spin vector T, which is equal to $\Sigma\tau$; and it has an orientation T_Z, which is equal to $\Sigma\tau_Z$. The symbolic space in which these orientations occur is called isobaric space; its Z-axis corresponds to the direction of observable (negative) charge. Nuclei with a common value of T_Z have the same neutron excess, equal to $2T_Z$, by the relationship:

$$T_Z Z = N(+\tfrac{1}{2}) + Z(-\tfrac{1}{2}) = \tfrac{1}{2}(N - Z)$$

where T_Z is as defined above, N is the number of neutrons in the nucleus and Z is its number of protons Both T and T_Z are integral for even values of A, and half-integral for odd values

QUANTUM NUMBER, MAGNETIC. A quantum number that determines the component of the angular momentum vector of an atomic electron or group of electrons along the externally applied magnetic field The values of these components are restricted, i e., quantized.

QUANTUM NUMBER, PRINCIPAL. A quantum number which, in the old Bohr model of the atom, determined the energy of an electron in one of the allowed orbits around the nucleus. In the theory of quantum mechanics the principal quantum number is used most commonly to identify the electronic orbital of the electrons.

QUANTUM NUMBER, RADIAL. In the Bohr theory of the atom, the quantum number that characterized the momentum of an electron in the direction of the radius vector.

QUANTUM NUMBER, SPIN. An integral term in the expression for the contribution to the total angular momentum of the electron that is due to the rotation of the electron on its own axis. This contribution is quantized, having two values $\frac{1}{2}$ and $-\frac{1}{2}$, in terms of $h/2\pi$ units of angular momentum (h = **Planck's constant**). The spin quantum number gives a numerical basis for the occurrence of many multiplet lines in ordinary spectra.

QUANTUM STATISTICS. Statistics of the distribution of particles of a given type among the various possible energy values, taking **quantization** of the latter into account, including the principle of the indistinguishability of the particles. In the **Fermi-Dirac statistics,** no more than one of a set of identical particles may occupy a particular quantum state (i.e., the **Pauli exclusion principle applies**) whereas in the **Bose-Einstein statistics,** the occupation number is not limited in any way. Particles described by these statistics are sometimes called fermions and bosons, respectively. No particle has been found to be neither a fermion nor a boson. All known fermions have total angular moments $(n + \frac{1}{2})h$, where n is zero, or an integer, and all known bosons have angular momentums nh. At sufficiently high temperatures, where a large number of energy levels are excited, both quantum statistics reduce to the classical **Maxwell-Boltzmann statistics.** The basis of the two quantum statistics is the observation that any **wave function** that involves identical **fermions** is always antisymmetric with respect to interchange of the coordinates, including spin, of any two of the fermions, whereas for identical **bosons,** the wave function is always symmetric.

QUANTUM THEORY OF HEAT CAPACITY. A theory which explains on the basis of energy quantization the decrease of specific heats at low temperatures to values below their classical values. For the case of regular solids, the formula of **Debye** forms a good approximation.

QUANTUM THEORY OF RADIATION. The energy of radiation emitted or absorbed is concentrated in quanta or photons each with an energy in ergs of 6.624×10^{-27} times the frequency of the radiation in cycles per second. (See also **Planck radiation formula.**)

QUANTUM THEORY OF SPECTRA. The present theory of spectra, which is based on an idea that there exist in each atom or molecule certain permitted energy levels. An atom or molecule absorbs or radiates energy as it moves from one energy level to another. The frequency (ν) of the radiation associated with such change of energy level is given by

$$E_1 - E_2 = h\nu$$

E_1, E_2 are the energy levels and h is the **Planck constant.**

QUANTUM YIELD. The number of photon-induced reactions of a specified type per photon absorbed. In the **photoelectric effect,** the quantum yield is more commonly called the **photoelectric efficiency.** In photochemistry it is the ratio of the number of reactions induced both directly and indirectly by light to the number of photons absorbed; a quantum yield greater than unity indicates a chain reaction. In plant physiology it is the ratio of the number of reactions of the primary photochemical step of photosynthesis (as yet undetermined) to the number of photons absorbed.

QUART. A unit of dry and liquid measure in the English system.

1 U.S. liquid quart	= 0.94633 liter
1 U.S. liquid quart	= 2 U.S. pints
4 U.S liquid quarts	= 1 U.S. gallon
1 Imperial quart	= 1.13650 liters
1 U.S. dry quart	= 1.1012 liters

QUARTER-WAVE PLATE. See **double refraction.**

QUARTZ CRYSTALS. A natural mineral composed of silicon dioxide, which crystallizes in hexagonal, positive, uniaxial crystals. Two sorts are found, one rotating the plane of polarization clockwise, the other counterclockwise. Since completely clear crystals of quartz are moderately common, and it is relatively hard (7 on the **Moh scale**) and easy to polish, quartz finds many uses in optical instruments, particularly those which use polarized light. Crystal quartz is transparent to shorter ultraviolet radiation, and to longer infrared radiation than is ordinary glass. It also has a broad band of fair transmission

for infrared, starting at about 50 microns and extending far into the still-longer, infrared region. Quartz crystals are also useful as **piezoelectric crystals.**

QUARTZ LAMP. See **lamp, quartz.**

QUASI-CONDUCTOR. If the **"Q" of a medium** is much less than unity, that medium is sometimes called a "quasi-conductor."

QUASI-DIELECTRIC. If the **"Q" of a medium** is much greater than unity, that medium is sometimes called a "quasi-dielectric"

QUASI-DIFFERENTIATION (INTEGRATION). Approximate differentiation (integration) by a simple circuit

QUASI FERMI LEVELS. In a **semiconductor** a potential energy defined so as to give either the number of **holes,** or of electrons in the **conduction band,** when the material is not in thermal equilibrium, as if it were the **Fermi level.**

QUASI-STATIONARY FRONT. See **front, quasi-stationary.**

QUATERNION. A hypercomplex number of the form

$$a_0 + \sum_{i=1}^{3} a_i e_i$$

where a_0 a_i are real numbers, and $e_i^2 = -1$, $e_1e_2 = -e_2e_1 = e_3$, etc. A quaternion of unit norm

$$(a_0^2 + \sum_{i=1}^{3} a_i^2 = 1)$$

may be used to represent a rotation in three dimensions. (See also **Euler-Rodrigues parameters.**)

QUENCH CIRCUIT. See **superregenerative receiver.**

QUENCHING FREQUENCY. The frequency of the local quenching oscillator (see **oscillator, quenching**) of a **superregenerative receiver.**

QUENCHING IN A GAS-FILLED RADIATION COUNTER TUBE. The process of terminating a discharge in a radiation **counter tube** by inhibiting **reignition.**

QUENCHING OF ORBITAL ANGULAR MOMENTUM. An electric field, such as the **crystal field,** may be so strong that it causes rapid precession of the orbit of an electron moving about an atom. As a result, the magnetic moment associated with the orbital angular momentum averages to zero.

"QUENCHING" OF RESONANCE RADIATION. Since the process whereby a "fast" electron, upon collision with an atom, excites or even ionizes it, losing energy in so doing, is called a **collision of the first kind,** then the reverse process is called a **collision of the second kind.** This latter process is then a collision of an excited atom with a "slow" electron to yield an unexcited atom and a "fast" electron. This process may result in the so-called "quenching" effect, as exemplified by the "quenching" of resonance radiation of mercury. For example, if the light from a quartz mercury arc is arranged to strike an evacuated quartz bulb containing a drop of mercury the resonance line (λ2537) is absorbed by the mercury vapor so that little or no radiation passes through the vapor directly. However, the bulb now acts as a source of radiation of the pure resonance line owing to excitation of normal atoms by the absorbed radiation, and subsequent spontaneous emission of this radiation occurs in all directions (scattered radiation). Such a source has been designated a resonance lamp. If the radiation from this source is now allowed to fall on another bulb containing mercury in a vacuum the same processes of absorption and re-emission of λ2637 are observed again. But if a gas such as nitrogen, water vapor, or hydrogen is introduced at low pressure into the second bulb, the intensity of the emitted radiation is decreased. It is said to have been "quenched."

QUIESCENT. This adjective is used in connection with vacuum tubes and other **amplifiers** to indicate the condition in which no **signal (1)** is applied to the input. The quiescent potentials of the various electrodes are therefore the *steady* undisturbed potentials of these electrodes, and the electrode currents are similarly defined.

QUIET AUTOMATIC VOLUME CONTROL. Delayed **automatic volume control.**

QUIET TUNING. See **interstation quieting.**

QUIETING SENSITIVITY (IN FM RECEIVERS). See **sensitivity quieting (in FM receivers).**

QUINCKE TUBE. A sound transmission tube with two parallel branches, used for sound filtration (See **filter, wave.**)

QUINHYDRONE ELECTRODE. See **electrode, quinhydrone.**

QUINTUPLE POINT. The temperature at which five **phases** are in equilibrium

R

R. (1) Gas constant (R), specific gas constant (r). (2) Degree Reamur (°R). (3) Degree Rankine (°R). (4) Radius (r), radius of nucleus (r_I), hydraulic radius (r_H). (5) Radius vector (r). (6) Radioactive range (R). (7) Roentgen (r). (8) Reluctance ($\mathcal{R}$). (9) Electric resistance (r or R). (10) Acoustic resistance (r). (11) Specific acoustic resistance (r). (12) Radiation resistance (R). (13) Thermal resistance (R). (14) Plate resistance (r_p). (15) Rydberg constant (R), Rydberg constant for infinite mass (R_∞). (16) Position vector (**r**). (17) Radiancy or radiant flux density ($\mathcal{R}$). (18) Angle of reflection (r). (19) Relative humidity (r). (20) Radius of acoustical tube, disc or membrane (R). (21) In spectroscopy, narrow self-reversal (r), wide self-reversal (R). (22) Orbital angular momentum of nuclei (rotational quantum number) (R).

R-BRANCH. See **Fortrat parabola.**

R-METER. Any **ionization** metering instrument calibrated to read in **roentgens.**

RAABE TEST. A test for absolute **convergence** of a series. If the absolute value of the ratio of successive terms for sufficiently large values of n can be written

$$\left|\frac{u_{n+1}}{u_n}\right| = 1 + \frac{k_1}{n} + \frac{k_2}{n^2} + \cdots$$

then the series converges absolutely if $k_1 < -1$ and diverges if $k_1 \geqq -1$. With slightly less generalization, the third term on the right may be replaced by $0(1/n^p)$, where $p > 1$; i.e., this term is of the **order of** $1/n^p$.

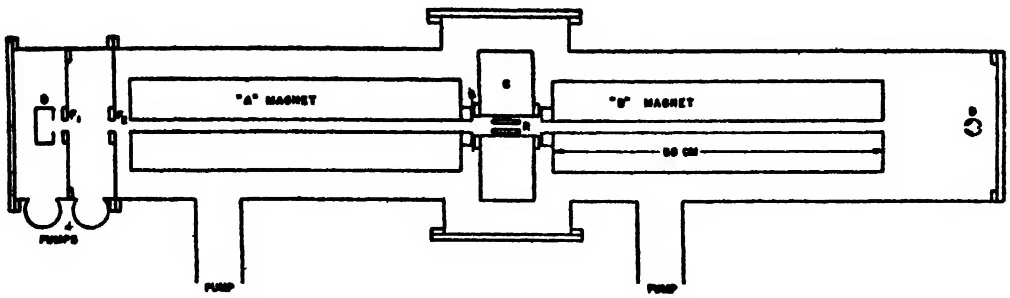
RABBIT. A small container propelled, usually pneumatically or hydraulically, through a tube in a nuclear **reactor** for exposing substances experimentally to the radiation and neutron flux of the active section; used for rapid removal of samples containing atoms with very short half-lives. (Sometimes called **shuttle.)**

RABI METHOD FOR DETERMINING NUCLEAR MOMENTS BY "RADIO-FREQUENCY SPECTROMETRY." The nucleus of an atom may itself have a **magnetic moment.** This is always much smaller than a Bohr magneton, and is detected most readily when the outer electronic structure is balanced magnetically so that its net moment is zero. Nuclear moments do not have any important influence on the magnetic properties of materials, but they are very important in the study of nuclear structure.

The particular method known as the "molecular beam resonance method" and used first by Rabi and his colleagues is as follows:

As in other experiments a molecular beam is provided and defined by slits. When the molecules enter the field, the vector representing the magnetic moment precesses around the direction of the field. About half of the molecules are deflected downward by the field gradient produced by magnet A, and upward by the gradient of magnet B, and arrive at the point D where they are detected by a suitable device. Molecules of different velocities are focused at the same point after traversing other paths, provided no change occurs in the magnetic moment along the path.

A change in the vertical component of the moment is produced in the uniform field H of magnet C by superposing upon the field a rather weak alternating field, of frequency f, produced by current in the copper tubes shown. The disturbing action of this field may best be explained by analogy with a spinning top precessing about a vertical axis under the influence of gravity. If a disturbing force is produced, as by oscillating the point of support, the top will become unstable, provided the frequency of oscillation is equal to the frequency of precession. In the case of the molecules, instability is produced when their frequency of precession (proportional to the field strength H) and the frequency of oscillation of the weaker field are equal, and unstable molecules then deviate from their previous paths as indicated by the dotted line



Molecular beam apparatus as used in the Rabi method.

E. H is varied slowly until the number of molecules arriving at D is a minimum, and H and f are noted.

The ratio of the magnetic moment to the angular moment is expressed in terms of the **Landé factor** g:

$$g = (4\pi Mc/e)f/H = 0.001312f/H,$$

M being now the mass of the proton. For the Li^7 atom, experiment gives $f = 5.61 \times 10^6$ cps, $H = 3400$ oersteds, and hence $g = 2.167$, and the magnetic moment is 3.25 nuclear **Bohr magnetons.**

RACEMIC. Optically inactive, but containing forms of opposed **optical activity.**

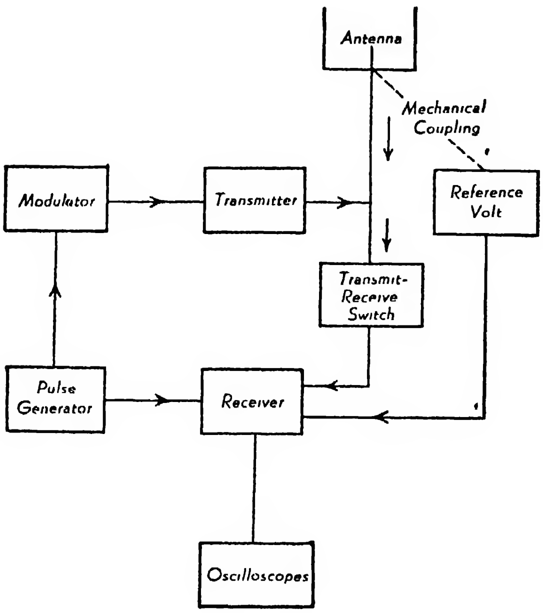
RACON. The **radar** beacon, a device that has been used for some time for the purpose of identifying ships and planes picked up on **radar** view scopes during military and naval operations. It is a standard aid for both air and sea **navigation** that may be used by all navigators supplied with radar.

RAD. A unit of absorbed dose, recommended by the International Commission on Radiological Units (July, 1953). It is 100 ergs per g.

RADAR. Radar (coined from *ra*dio *d*irecting *a*nd *r*anging) is a system for locating reflecting objects by means of radio signals. Anything which will reflect enough energy of a radio signal of high frequency to actuate the **receiver** may be detected and accurately located in space over distances approximating line-of-sight distances from the radar stations. This will be over 100 miles for high-flying planes. Since the radio signals penetrate fog, darkness, rain, and haze, this method of locating planes, ships, and ground objects does not have many of the limitations of the older optical systems. In addition, the ranging by radar means may be much more accurate than that of the optical methods. Although radar was originated a number of years ago, it was not until just before and during World War II that it was brought to the high degree of perfection which permitted its use in detecting enemy equipment and then controlling the gunfire which destroyed that equipment, often without the enemy being visible. Because of the varied reflecting characteristics of many ground installations, bodies of water, types of earth, terrain formations, etc., certain types of radar were used for blind bombing when visual sighting was impossible. These war-developed applications point the way to many obvious peacetime applications such as blind navigation of ships in heavy fogs, blind flying, blind landings, and storm tracking.

Although the details of the various radar systems differ, depending upon the particular type and the use for which it is intended, the basic principles are the same. A series of accurately timed and very short pulses of radio frequency (frequencies range from approximately 100 to several thousand megacycles) are transmitted by a **directional antenna.** Since these pulses represent only a small part of the total time, the power in the pulse may be quite high without the average power (and hence size of equipment) becoming excessive. If these radio signals strike a conducting object some of the energy is reflected. The reflected pulses may then be picked up by the radar receiving system. Basically the direction of the antenna when a reflection is detected gives the direction to the object, and the time between the transmission of the pulse and its return gives the distance (radio waves travel at 186,000 miles per sec). The details of making the system sufficiently accurate for practical use are very

complex, but the principles may be illustrated by considering a unit used for search and fire control against aircraft. The figure shows a simplified block diagram of the unit. The



timing unit or **pulse generator** controls the sequence of operations by supplying a keying pulse to the transmitting system and at the same time a reference pulse to the receiving system. The pulse is shaped and amplified in the modulator unit and is then applied to the **transmitter.** Here it serves to key the pulse of radio-frequency energy, the high-frequency pulse being fed to the antenna. The field to be observed is scanned by the antenna and its radio signal just as it might be scanned by a searchlight and its beam for visual searching. Various types of antenna structures are used, but all are directional, and the direction may be changed at will. Some radars use separate transmitting and receiving antennas, although most use a common antenna for both functions. The T-R unit is merely an electronic switch which cuts out the receiver circuits when a pulse is being transmitted and then opens them between transmitted pulses so they will be ready for the received pulses. The range of the radar is limited by the distance the signal can travel out and back between transmitted pulses, since one pulse must make its complete trip before the next one starts. The received signal is compared in the receiver with the signal originally generated in the pulse generator, the time difference giving the time of travel of the radio wave and hence the distance. There are various methods of doing this, but **cathode ray oscilloscopes** are used as the comparison indicators. As an elementary example, suppose the signal received from the pulse generator initiates the sweep circuit of the oscilloscope and that the sweep takes a definite and known time to traverse the oscilloscope screen. This may be accurately adjusted by means of the circuit constants of the sweep circuit. If the returned signal from the receiver is fed to the other set of plates of the oscilloscope, it will appear as a hump or "pip" on the trace. If, for example, the sweep time is 100 microseconds and the pip occurs at a point one fourth of the distance across the scope, the time of travel of the radio wave would be $\frac{1}{4} \times 100$, or 25 microseconds, and the distance to the detected object would be $\frac{1}{2} \times 25 \times 10^{-6} \times 186{,}000$, or 2.32 miles. This simple illustration neglects, of course, time delays in the circuits, but these are allowed for easily. In many cases they are adjustable to improve the accuracy of ranging. Connected with the antenna scanning mechanism is a reference voltage generator whose output is also fed into the receiving system to indicate direction to the reflecting plane when a pulse is received. By electronic means this reference voltage may be compared with the received pulse in such a way as to indicate on a scope to the radar operator when he is pointing directly at the target.

In a PPI (plan position indicator) system the movement of the antenna is tracked by the trace of an oscilloscope tube (the PPI scope). Thus, the position of the trace on the scope corresponds to the direction of the beam from the antenna. A reflection then appears as a bright spot on the oscilloscope, the azimuth of the spot being the azimuth of the reflecting object and the distance of the spot from the center indicating the range of the object. The intensity of the spot is a measure of the reflecting efficiency of the target. Thus, when such a radar is used from a plane, the antenna being used to scan the area below, the oscilloscope will show a shaded pattern of the ground since the reflection is affected by changes of terrain, different building materials, bodies of water, etc. As the radar beam sweeps over points with high-reflection coefficients the spot is bright, whereas points with lesser coefficients give less bright regions

on the scope. The result on the screen is a picture of the area being viewed, appearing very much like an aerial photograph.

RADAR, DOPPLER. See **Doppler radar.**

RADAR EQUATION. For a **radar** system using the same antenna for transmission and reception, the maximum range at which an object can be detected is proportional to the fourth root of the **transmitted power,** the square root of the **antenna area,** and the square root of the frequency.

RADAR "ECHO." The reflected, radio-frequency energy from objects surrounding the **radar** transmitter.

RADAR, FIXED-TARGET REJECTION. See **moving target indicator.**

RADAR INDICATORS. **Cathode-ray oscilloscopes** which present the returned signal for visual observation. Several of the different types of presentation are as follows:

The "A" indicator presents signal intensity against a time-base sweep which is calibrated in range. The "B" indicator presents range on one axis against azimuth on the other axis The intensity of this display is brightened as a function of echo intensity. The "C" indicator also employs intensity brightening with echo strength, and presents azimuth against elevation.

The "J" presentation is similar to the "A," but bends the range sweep around the periphery of the cathode-ray indicator tube to obtain a longer range trace. The PPI (plan position indicator) presents a map picture of the surrounding area by displaying azimuth angle and range in their actual relationship. Echoes are indicated by increased trace intensity.

RADAR, MOVING-TARGET INDICATION. See **moving-target indicator.**

RADAR PULSE DURATION, LENGTH OR WIDTH. The length of the **radar** transmission, usually expressed in microseconds.

RADAR PULSE-REPETITION FREQUENCY. The number of **radar** transmissions made per second.

RADAR "TARGET." Any reflecting surface in the beam of the **radar** antenna which causes a signal to be returned to the receiver.

RADIAL BEAM TUBE. A switching tube (see **tube, switching**) which employs a radial beam of electrons which is rotated around the cathode by the magnetic field produced by an external coil assembly. Anodes placed along the circumference of a circle having the cathode as its center are swept by the beam twice in each beam-revolution.

RADIAL DISTRIBUTION FUNCTION. The radial distribution function for a liquid is defined as the function $\rho(r)$, where $4\pi r^2\rho(r)dr$ is the average number of molecule centers at distances between r and $r + dr$ from some selected molecule. If the liquid is isotropic, it is the average number density at distance r from the selected molecule. The radial distribution function may be computed from measurements of X-ray **diffraction patterns,** and it is of central importance in the **kinetic theory of liquids.**

RADIAL DISTRIBUTION METHOD. A statistical method for the analysis of data obtained by measuring the intensity of **x-ray diffraction** at various angles, in order to determine interatomic distances of liquids and gases, within certain limitations.

RADIAL GRATING. An E mode (zero order) **suppressor** for a circular **waveguide,** consisting of radial wires placed in the guide.

RADIAL TRANSMISSION LINE. See **transmission line, radial.**

RADIAN. A unit for measuring angles. It is that angle whose intercepted arc in a circle equals the radius of the circle. Thus π **radians** $= 180°$; 1 radian $= 180°/\pi = 57.29578\cdots°$ or $57°\ 17'\ 44.6''$, approximately, and $1°$ is approximately 0.017453 radians.

RADIANCE. The **radiant flux** per unit solid angle per unit of projected area of the source The usual unit is the watt/steradian/square meter. This is the radiant analog of luminance. The International Commission on Illumination recommends the word be abandoned in favor of emittance, luminous or radiant, for flux emitted per unit area.

RADIANT. A term denoting motion on a radius or, more particularly, along a very great number of radii, as the emission of energy from a point source, which travels along the various radii of a sphere of constantly-increasing radius, so that the **radia-**

tion-pattern at any instant occupies, in a perfectly homogeneous medium, the position of the surface of a sphere. From this original meaning, the term has been extended in its application to connote either particles of matter or electromagnetic energy emerging from a more or less sharply defined region, or the substance or entity which emits such particles or radiations.

RADIANT EMITTANCE. See **emittance.**

RADIANT ENERGY. Energy transmitted as electromagnetic **radiation.**

RADIANT FLUX. The time rate of flow of radiant energy.

RADIANT FLUX DENSITY. A measure of radiant power per unit area that flows across or onto a surface. (Also called **irradiance.**)

RADIANT INTENSITY. The energy emitted per unit time, per unit solid angle about the direction considered; for example, **watts per steradian.**

RADIANT SENSITIVITY (OF A PHOTOTUBE). The quotient of output current by incident radiant flux of a given wavelength at constant electrode voltages. The term output current as here used does not include the **dark current.**

RADIATED POWER, EFFECTIVE. The product of the **antenna power** (transmitter output power less transmission line loss) times (a) the **antenna power gain,** or (b) the **antenna field gain** squared.

RADIATION. (1) The emission and propagation of energy through space or through a material medium in the form of waves; for instance, the emission and propagation of electromagnetic waves, or of sound and elastic waves. (2) The energy propagated through space or through a material medium as waves; for example, energy in the form of electromagnetic waves or of elastic waves. The term radiation, or radiant energy, when unqualified, usually refers to electromagnetic radiation; such radiation commonly is classified, according to frequency, as Hertzian, infra-red, visible (light), ultraviolet, x-rays, and γ-rays. (See **photon;** also **radiation field;** also entries under **ray** and **radiation.**) (3) Corpuscular emissions, such as α- and β-radiation, or rays of mixed or unknown type, as cosmic radiation.

RADIATION, ČERENKOV. Radiation emitted by a high-energy charged particle moving in a medium having an index of refraction considerably greater than unity. This radiation is due to the effect of the discrepancy between the high velocity of the particle, which may be close to that of light in a vacuum, and the lower velocity of its associated electric and magnetic fields, which have a velocity equal only to the velocity of light in a vacuum *divided by* the **refractive index** of the medium.

RADIATION, COHERENT. See **coherent radiation.**

RADIATION CONSTANTS. See the **Planck radiation formula.**

RADIATION, COSMIC. See **cosmic rays.**

RADIATION COUNTER. See **counter.**

RADIATION DENSITY CONSTANT. The constant used in the **Stefan-Boltzmann law** to express the total energy density of **black body** radiation as a function of the temperature.

$$a = 8\pi^5k^4/15c^3h^3$$
$$= 7.569 \times 10^{-15} \text{ erg cm}^{-3} \text{ deg}^{-4}.$$

RADIATION, ELECTROMAGNETIC. See **electromagnetic radiation.**

RADIATION EFFICIENCY. The ratio of the power radiated to the total power supplied to an **antenna** at a given frequency.

RADIATION FIELD. When a conductor carries a-c there are two types of fields set up in the surrounding space. One of these, the induction field, is predominant at low frequencies such as used in power circuits while the other, called the radiation field, predominates at very high frequencies such as used for **radio communication.** The induction field is responsible for the familiar magnetic effects of **coils** and the interference between circuits which are coupled inductively, i.e., the induction field of one links the other. For radio communication over long distances the radiation field is important since it represents the energy which is radiated outward from the **antenna** system and which does not return to the system but spreads out in space. Close to

the transmitting station both types of field may be utilized; in fact, certain wireless record players use the induction field, but at appreciable distances (a few wavelengths) the induction field is negligible. The radiation field consists of an electromagnetic wave traveling at the velocity of light (3×10^{10} cm/sec). It is this wave which cuts across the receiving antenna and induces the signal which is amplified and demodulated in the **receiver.** This radiation goes out from the antenna in various directions, the exact directions and strengths being dependent upon the antenna characteristics. Thus some of the energy may travel along the earth's surface to the receiver, some may go upward to the **ionosphere** and be refracted so it is returned to the earth giving long-distance communication. This radiation field is composed of an electric and a magnetic component, mutually perpendicular and perpendicular to the direction of propagation Upon leaving the antenna the electric field is parallel to the antenna and the magnetic perpendicular to it. Either or both may contribute to the signal induced in the receiving antenna. At extremely high frequencies the polarization or direction of the electric field or vector has an effect on the character of the received signal.

RADIATION, FLUORESCENT METHOD OF DETECTING. The detection of radiation by means of the **fluorescence** produced in a suitable screen, such as zinc sulfide.

RADIATION, HETEROGENEOUS. Radiation having several different frequencies, or a beam of particles of a variety of energies or containing different types of particles.

RADIATION, HOMOGENEOUS. Radiation having an extremely narrow band of frequencies, or a beam of monoenergetic particles of a single type.

RADIATION, INFRARED. See **infrared radiation.**

RADIATION INTENSITY. In a given direction, the power radiated from an **antenna** per unit solid angle in that direction.

RADIATION, LEAKAGE. In a transmitting system, radiation from anything other than the intended radiating system.

RADIATION LENGTH. The mean path length required for the reduction, by the factor $1/e$, of the energy of relativistic charged particles as they pass through matter. Such particles lose their energy mainly by radiating (see **bremsstrahlung**). The radiation length for relativistic electrons in air is 330 m; in lead it is 0.5 cm.

RADIATION LOBE. A portion of the **radiation pattern** bounded by one or two cones of **nulls.**

RADIATION LOSS. That part of the **transmission loss** due to radiation of radio frequency power from a transmission system.

RADIATION, MONOCHROMATIC. Radiation having one frequency or one wavelength. Actually, no finite amount of radiation will ever be strictly monochromatic. It will, at best, contain a narrow band of wavelengths.

RADIATION PATTERN. A graphical representation of the radiation of the **antenna** as a function of direction. Cross sections in which radiation patterns are frequently given are vertical planes and the horizontal plane, or the principal electric and magnetic polarization planes.

RADIATION, PHOTOGRAPHIC METHOD OF DETECTING. The detection of radiation by means of its action on a photographic film or plate; or the detection of the passage of a heavily ionizing particle through a photographic emulsion by its activation of individual crystal grains in the emulsion.

RADIATION POTENTIAL. The potential difference in volts corresponding to the energy in electron-volts required to excite an atom or a molecule to emit one of its characteristic radiation-frequencies.

RADIATION PRESSURE. (1) That **electromagnetic radiation** exerts a pressure upon any surface exposed to it was deduced theoretically by Maxwell in 1871, and proved experimentally by Lebedew in 1900 and by Nichols and Hull in 1901. The pressure is very feeble, but can be detected by allowing the radiation to fall upon a delicately poised vane of polished metal. (See **Nichols radiometer.**) It may be shown by the electromagnetic theory, by the **quantum theory,** or by **thermodynamic** reasoning, making no assumption as to the nature of radiation, that the pressure against a surface exposed in a space traversed by

radiation uniformly in all directions is equal to ⅓ the total radiant energy per unit volume within that space. For **black-body** radiation, in equilibrium with the exposed surface, the energy density is, in accordance with the **Stefan-Boltzmann law,** equal to $(4\sigma/c)T^4$; in which σ is the Stefan-Boltzmann constant, c is the **electromagnetic constant,** and T is the absolute temperature of the space. One-third of this energy density is equal to $2.523 \times 10^{-15}T^4$ (ergs/cm³), which is therefore the pressure in bars. (2) In acoustics, radiation pressure is the unidirectional pressure force exerted at an interface between two media due to the passage of a **sound wave.**

RADIATION PYROMETER. A **pyrometer,** of which there are several commercial designs, based upon the principle that the intensity of the thermal radiation from a heated body depends in a systematic way upon the temperature of its surface. The essential mechanism involves the focusing of the radiation upon a thermocouple or some other sensitive thermometric detector by means of a suitable mirror. In one form the mirror is concave, producing a real image of a portion of the heated surface; in another it is a hollow cone, in which the radiation converges in an opening at the apex, where the thermocouple is placed. All instruments of this type must be experimentally calibrated, as temperatures computed theoretically from the **Stefan-Boltzmann law** are, for various reasons, found to be in error A fundamental difficulty arises from the fact that no actual radiator is an ideal **black body,** and the emissive power of one surface differs from that of another at the same temperature. This gives rise to the term "radiation temperature" as different from the actual temperature of the body under examination.

In addition to the foregoing type, sometimes called the "total radiation pyrometer," the **spectrophotometer** or the spectroradiometer (an infrared spectrophotometer) is used in the case of very high temperatures, and the temperature deduced from the "peak" wavelength in accordance with the Wien displacement law. (See **Wien laws.**)

RADIATION, RECOIL. A term applied to radiations emitted during **nuclear disintegrations** which are attended by an observable recoil of the nucleus emitting the radiation.

RADIATION RESISTANCE. (1) The quotient of the power radiated by an **antenna** by the square of the **effective antenna current** referred to a specified point. (2) The (acoustic) radiation resistance of a medium is the acoustic impedance (see **impedance, acoustic**) of a plane wave, equal to $\rho_0 c/S$ where ρ_0 is the mean density of the medium in gm/cm³, c is the velocity of sound in cm/sec, and S is the area of the **wave front** under consideration in cm².

RADIATION, RESONANCE. See **resonance radiation.**

RADIATION, STRAY. All radiation which reaches the detector at wavelengths that do not correspond to the spectral position under consideration.

RADIATION, ULTRAVIOLET. See **ultraviolet radiation.**

RADIATION, VISIBLE. Radiant energy which is perceived by the normal eye (approximately 3800 to 7800 Å). (See also **infrared** and **ultraviolet radiation.**)

RADIATIONLESS DECOMPOSITION OR TRANSITION. See **Auger process** and **collision of the second kind.**

RADIATIVE CAPTURE. See **capture, radiative.**

RADIATIVE CORRECTION. Difference between the theoretical values of some property of a dynamical system as computed from the quantized field theory (see **field theory, quantized**) of the system and from the corresponding unquantized field theory. Applied particularly to the theory of electrons, positrons and the electromagnetic field. (See **Lamb shift, anomalous magnetic moment (electron), vacuum polarization, self-energy, renormalization.**)

RADIATOR. (1) A body which emits energy quanta or certain material particles; more commonly a body which emits **electromagnetic radiation.** (2) A substance placed in a beam of radiation, which as a result of the interaction of the beam with the substance, emits radiation of a different type. For example, a metal foil placed in a beam of γ-radiation will emit secondary electrons as a result of the **photoelectric** and **pair production** processes. (3) A **radiating element,**

which may be (a) a vibrating element in a **transducer** which can cause, or be actuated by sound waves, or (b) a basic subdivision of an **antenna,** which in itself is capable of radiating or receiving radio-frequency energy.

RADIATOR, COMPLETE. See **complete radiator.**

RADIATOR, NON-SELECTIVE. A radiator whose spectral emissivity (see **emissivity, spectral**) remains constant throughout the spectrum, being in a constant ratio to that of a complete radiator (see **radiator, complete**) at the same temperature. (Also called a "gray body.")

RADIATOR, SPHERICAL OR ISOTROPIC. A **radiator** which produces the same radiation intensity in all directions.

RADICAL. (1) An indicated root of a number, usually a principal root; thus, the radical symbol $\sqrt[n]{a}$ means the principal nth root of a. Operations with radicals are expressed by the formulas:

$$\sqrt[n]{ab} = \sqrt[n]{a}\sqrt[n]{b}$$
$$\sqrt[n]{\frac{a}{b}} = \frac{\sqrt[n]{a}}{\sqrt[n]{b}}$$

if a and b are positive. Such functions or equations containing them are also called irrational. (2) A group of atoms which may enter into several combinations as a unit, and take part in reactions like an elementary substance, vis., NH_4—, CH_3—, C_6H_5—, C_6H_5CO—, $=SO_4$.

RADIOACTINIUM. A **thorium** isotope of mass number 227, produced naturally by β-decay of **actinium** 227. Radioactinium emits α-particles (half-period 18.8 days) to give radium 223 (actinium X).

RADIOACTIVE. Exhibiting or pertaining to **radioactivity.**

RADIOACTIVE CHAIN. A synonym for **radioactive series.**

RADIOACTIVE CONSTANT. Discussed under **disintegration constant.**

RADIOACTIVE DECAY. See **radioactivity;** and **decay, radioactive.**

RADIOACTIVE DECAY CONSTANT. See **disintegration constant.**

RADIOACTIVE DECAY LAW. See **decay law, radioactive.**

RADIOACTIVE DISINTEGRATION. See **radioactivity.**

RADIOACTIVE DISPLACEMENT LAW. A law originally stated by Soddy and Fajans. In its more modern and inclusive form it may be stated as follows: When a nucleus emits an α-particle the new nucleus formed has an **atomic number** two less than the parent and a **mass number** of four less. When a nucleus emits a negative β-particle the atomic number of the new nucleus formed is one greater than the parent and the mass number remains the same. The emission of a positron or the capture of an orbital electron decreases the atomic number by one without changing the mass number. Isomeric transition and γ-emission lead to no change in atomic number or mass number.

RADIOACTIVE EMANATIONS. Radioactive gases given off by certain radioactive elements. Thus, **radium, thorium,** and **actinium** give off the radioactive gaseous emanations, **radon, thoron,** and **actinon,** respectively.

RADIOACTIVE EQUILIBRIUM. A condition which may obtain in the course of the decay of a radioactive parent having shorter-lived descendants, in which the ratio of the activity of the parent to that of a descendant is independent of time. This condition can exist only when no activity longer-lived than that of the parent is interposed in the **decay chain.** If the **half-life** of the parent is long compared to the time of the experiment then the state is called secular equilibrium. When secular equilibrium exists among members A, B, C, $\cdots$ etc., of a decay series, then $N_A\lambda_A = N_B\lambda_B = N_C\lambda_C = \cdots$ where N_A, N_B, N_C, $\cdots$ are the numbers of atoms of $A, B, C, \cdots$, respectively, and λ_A, λ_B, λ_C, $\cdots$ are the corresponding **decay constants.** If the half-life of the parent is short and a decline in parent activity is observable, the state is called transient equilibrium. When transient equilibrium exists between a parent, A, and daughter, B, then $N_A\lambda_A = N_B(\lambda_B - \lambda_A)$ where N_A and N_B are the number of atoms and λ_A and λ_B the respective **decay constants.**

RADIOACTIVE HEAT. A synonym for radiogenic heat. (See **radiogenic.**)

RADIOACTIVE ISOTOPE. An isotope which is radioactive.

RADIOACTIVE NUCLIDES, NATURAL. Natural radioactive nuclides may be classified as follows: (1) primary, which have lifetimes exceeding about 10^9 yr and presumably have persisted from the time of **nucleogenesis** to the present; they include the α-emitters U^{238}, U^{235}, Th^{232}, Sm^{147} and the β-disintegrators K^{40}, Rb^{87}, In^{115}, La^{138}, Lu^{136}, Re^{187}; (2) secondary, which are formed in radioactive transformations starting with U^{238}, U^{235} or Th^{232}; these three nuclides are the parents of the uranium series, the actinium series, and the thorium series of natural radioactive nuclides respectively; known members of this class all belong to the elements from thallium to uranium; (3) induced, having geologically short lifetimes and formed by induced nuclear reactions currently occurring in nature; examples are C^{14} (natural radiocarbon), produced by cosmic ray neutrons in the atmosphere, and Pu^{239}, produced in uranium minerals by neutron capture; (4) extinct, of lifetimes too short for survival from the time of nucleogenesis to the present, but long enough for persistence into early geologic times with measurable effects; at present I^{129} is the only suspected member of this class.

RADIOACTIVE SERIES. A succession of **nuclides**, each of which transforms by **radioactive disintegration** into the next until a stable nuclide results. The first member is called the parent, the intermediate members are called daughters, and the final stable member is called the end product. Three such series are encountered in natural radioactivity, and many others are encountered in induced radioactivity, particularly among the heavy elements and fission products. The process of successive radioactive transformations in such a series is known as series disintegration. A series of induced radionuclides that merges into a natural series is called a collateral series to the latter.

RADIOACTIVE STANDARD. A sample of radioactive material, usually with a long half-life, in which the number and type of radioactive atoms at a definite reference time is known. Hence, it may be used as a radiation source for calibrating radiation-measurement equipment.

RADIOACTIVITY. (1) Spontaneous nuclear disintegration with emission of corpuscular or electromagnetic radiations. The principal types of radioactivity are **α-disintegration, β-decay (negatron emission, positron emission,** and **electron capture)** and **isomeric transition.** Double β-decay is another type that has been postulated, and spontaneous fission and the spontaneous transformations of mesons are sometimes considered as types of radioactivity. To be considered as radioactive, a process must have a measurable lifetime (between $\sim 10^{-10}$ sec and $\sim 10^{17}$ yr, according to present experimental techniques). Radiations emitted within a time too short for measurement are called prompt; however, prompt radiations, including γ-rays, characteristic x-rays, conversion and Auger electrons, delayed neutrons, and annihilation radiation, are often associated with radioactive disintegrations, since their emission may follow the primary radioactive process. (2) A particular radiation component from a radioactive source, such as γ-radioactivity. (3) A radionuclide, such as a radioactivity produced in a bombardment. (4) A synonym for **activity.**

RADIOACTIVITY, ARTIFICIAL. Radioactivity induced in an element by bombarding it with particles or radiations or both (See **radioactivity** and **radioactivity, induced.**)

RADIOACTIVITY, INDUCED. The production of radioactive elements by bombardment of other elements, commonly the stable ones, with **α-particles, neutrons, protons,** and other particles or radiations. The artificial radioactive elements (commonly called radioelements) usually, but not always, have short life periods; they emit **electrons, positrons,** and other particles, as well as **γ-rays,** in their decomposition. (See **reaction, nuclear.**)

RADIO BEACON. A radio transmitting station, maintained and operated for the purpose of determination of **radio bearings.** The transmitting frequency, **latitude** and **longitude,** characteristic signal, and times of operation of each radio beacon are listed for sea navigators in the Hydrographic Office Publication "Radio Aids for Navigators," and for aviators in a similar publication of the Civil Aeronautics Administration. In one sense of the term, any **radio station** might

be used as a radio beacon since a radio bearing may be obtained from it. However, only stations listed as beacons can be relied upon, since their positions are carefully determined, and their signal characteristics are maintained by responsible agents.

RADIO BEARING. The direction of a radio transmitter, as determined by a **directional antenna receiver,** is known as the radio bearing of the transmitter.

RADIO BROADCASTING. **Radio transmission** intended for general reception.

RADIO CHANNEL. A band of frequencies of a width sufficient to permit its use for **radio communication.** The width of a channel depends upon the type of transmission, and the tolerance for the frequency of emission.

RADIO COMMUNICATION. Communication between distant points not directly connected by an electrical conductor may be accomplished by electromagnetic waves radiated through space Thus radio communication utilizes radiated energy instead of the conducted energy of the wired methods (see **radiation field**) Obvious benefits of the radio method are the elimination of the expense of installation and upkeep of a wire communication system, and the communication between points difficult of access by wired systems Furthermore, since energy may be radiated in all directions in space, broadcasting to large numbers of persons is simpler. Radiated electromagnetic waves can be used for communication purposes in three ways First, they may be used to create a monotone signal of dots and dashes comprising a code. This is **radio telegraphy.** It has certain important commercial and governmental uses, but is not suitable for broadcasting, as it must be interpreted by trained operators Secondly, electromagnetic waves may be modulated so that they carry the electrical equivalent of sound waves. At the receiver they are caused to reproduce the original sound, whether it was voice or music. This is the field of **radio telephony** and **broadcasting.** Thirdly, it is possible to transmit, by means of these waves, electrical pulses which will re-create at the point of reception, a scene which originated at the transmitter, with accompanying sound. This is **television.**

RADIO COMMUNICATION CIRCUIT. A **radio system** for carrying out one communication at a time in either direction between two points.

RADIO COMPASS. This is probably the most loosely used term in all **navigation.** When the **loop antenna** was first applied to the determination of **radio bearings,** the term radio-compass station was applied to shore installations that would forward, on request, the bearing of a ship from the station. Next the term was applied to a group of shore installations, each equipped with a loop antenna, from which the navigating officer of a ship within range could obtain the **latitude** and **longitude** of his ship. After the loop antenna and receiving sets had been developed to a state where they could be carried by the ships themselves, the term radio compass was applied to the loop. As new and improved radio equipment became available, the term radio compass was successively applied to any radio device that could be used to determine bearing A glance through any textbook on navigation, particularly those dealing with air navigation, will yield at least two, and sometimes as many as five, different instruments for the name radio compass.

RADIO COMPASS, DUAL-AUTOMATIC. A pair of **direction-finders,** with a common azimuth-indicator having a pointer for each direction finder, for the purpose of indicating the bearing automatically.

RADIOELEMENT. A form or sample of an element containing one or more **radioactive isotopes.** The prefix radio before the name of an element indicates a particular radioelement, as radiocarbon, radiolead. To avoid ambiguity, the prefix radio should not be used to indicate **radiogenic,** thus, radiolead should not be used as a synonym for radiogenic lead.

RADIO FADE-OUT. See **fading.**

RADIO FIELD INTENSITY. See **radio field strength.**

RADIO FIELD STRENGTH. The **electric** or **magnetic field strength** at a given location resulting from the passage of radio waves. In the case of a sinusoidal wave, the **root-mean-square** value is commonly used. Unless otherwise stated, it is taken in the direction of maximum.

RADIO FIELD-TO-NOISE RATIO. The ratio of the **field strength** of the desired wave to the field strength of the noise, measured at a given location.

RADIO FIX. A radio bearing or bearings to determine geographical position.

RADIO FREQUENCY. A frequency at which coherent electromagnetic radiation of energy is useful for communication purposes

RADIO-FREQUENCY ALTERNATOR. A rotating-type **generator** for producing radio-frequency power.

RADIO-FREQUENCY PULSE. See **pulse, radio-frequency.**

RADIOGENIC. Produced by radioactive transformation Thus, uranium minerals contain radiogenic lead and radiogenic helium. The heat produced within the earth by the disintegration of radioactive nuclides is known as radiogenic heat.

RADIOGRAPHY. Photography by x-ray radiation or by the γ-rays of radium or **radioactive substances.**

In making radiographs, the x-rays emitted from the anode of the tube (see **x-rays**) are directed towards the subject to be examined Upon reaching the subject some pass through while others, meeting parts of the subject which offer greater resistance, are absorbed wholly or partially. Thus a shadow of those parts of the subject which are more opaque to the passage of the rays is cast on the photographic film and, upon development, a shadow image of the variations in the transparency of the subject to x-ray radiation is obtained. This photographic image is termed a radiograph.

While all photographic materials are sensitive to x-ray radiation, special x-ray emulsions are available which are more sensitive, thus permitting shorter exposures, and have the high contrast necessary to differentiate between slight variations in the absorption of x-rays by different parts of the subject Such films differ from those used in the camera in having much thicker emulsion coatings; sensitivity to x-ray radiation depending largely upon the amount o' silver halide present for the formation of an image and not, as with light, on the sensitivity of the different grains of silver halide in the emulsion.

When the exposure must be kept as short as possible as, for example, in photographing organs of the body which cannot be immobilized, or thick sections, intensifying screens are used. These are screens coated with a fluorescent substance, such as calcium tungstate, which convert some of the x-ray energy into ordinary light and so reduce the exposure Placed in contact with the photographic emulsion an intensifying screen may reduce the exposure to $\frac{1}{25}$ the exposure required by direct exposure to x-ray radiation. With thick metallic castings the reduction in exposure may in some cases reach $\frac{1}{100}$.

RADIO HORIZON. The locus of points at which direct rays from the **transmitter** become tangential to the earth's surface. On a spherical surface the horizon is a circle. The distance to the horizon is affected by atmospheric refraction.

RADIO INTERFERENCE. Any **noise** which interferes with the reception of a desired signal.

RADIOISOTOPE. A synonym for **radioactive isotope.**

RADIOLOCATION. A British term for **radar.**

RADIOLUMINESCENCE. **Luminescence** as a result of radiant energy bombardment

RADIO MARKER BEACON. See **marker beacon.**

RADIO MARKER STATION. See **marker station.**

RADIOMETEOROGRAPH. A **meteorograph** utilizing small radio transmitters to send modulated signals which have equivalents in temperature, humidity, and pressure A balloon carries the measuring devices and the transmitter aloft to great altitudes. Four different methods of sending the signals are used: (1) time-spaced signals, (2) audio-frequency change, (3) radio-frequency change, and (4) codes. Measurements of temperature, relative humidity, and pressure are introduced into the transmitter which transmits the measurements in terms of a radio signal An electrical thermometer is generally used. The humidity element is usually a special human-hair instrument (see **hygrometer, hair**) or an absorption instrument which utilizes

change in the electrical resistance of lithium chloride in a thin film on a tube. Pressure elements are generally **aneroid** cells. Furthermore, by tracking the path of the radiometeorograph through the atmosphere, as with a suitable **direction-finder,** information is obtained concerning wind velocity at various heights.

RADIOMETER. An instrument for detecting, and usually also for measuring, radiant energy. Among the many types are the **Crookes radiometer** and the **Nichols radiometer** (these two being sometimes called "vane radiometers"). In addition to these, the **pyrheliometer,** the **bolometer,** the **radiomicrometer** and the **thermopile** may also be classed as radiometers.

RADIOMETER, ACOUSTIC. An instrument for measuring **sound intensity** by determining the unidirectional steady-state pressure caused by the reflection or absorption of a sound wave at a boundary.

RADIOMETRY. The measurement of radiant energy as with a **radiometer.**

RADIOMICROMETER. An instrument consisting primarily of an extremely sensitive thermocouple, suspended in a magnetic field, for measuring minute variations in radiation

RADIO NAVIGATION. The use of radio aids to **navigation** for checking the **dead-reckoning** position of a ship. Following a **radio range,** or using a **radio compass,** is included in the general subject of radio navigation.

RADIONUCLIDE. A **nuclide** which exhibits **radioactivity,** whether of artificial or natural origin. (See also **radioactive nuclides, natural.**)

RADIOPAQUE. Impenetrable to radiation.

RADIO-PHOTOLUMINESCENCE. **Luminescence** exhibited by certain minerals as a result of irradiation with β- and γ-rays, followed by exposure to light.

RADIO PROXIMITY FUSE. A radio device contained in a missile to detonate it within predetermined limits of distance from a target, by means of electromagnetic interaction with the target.

RADIO-RANGE BEACON, EQUISIGNAL. See **equisignal radio-range beacon.**

RADIO RECEIVER. See **receiver (radio).**

RADIOSENSITIVE. Sensitive to radiation.

RADIO SILENCE. See **international radio silence.**

RADIOSONDE. An instrument which fulfills the same functions as the **aerometeorograph** but to much greater altitudes. A small pilot balloon carries the instrument aloft; a small parachute lowers it to earth again when the balloon bursts in the upper atmosphere By means of a small clockwork motor and very light weight radio-transmitting set, the indications of instruments sensitive to pressure, temperature and humidity are automatically transmitted at regular intervals during the flight. The signals from the radiosonde are received and recorded on a special receiver on the ground, and are then translated into readings of pressure, temperature and humidity at the various altitudes.

RADIO SPECTRUM. See **spectrum.**

RADIO TELEGRAPHY. Radio telegraphy is that form of radio communication which utilizes the dots and dashes of a code, commonly the International code, to transmit the intelligence. Basically the system involves some generator of high-frequency **(radio-frequency)** a-c which can be interrupted according to the code and which is fed to the transmitting **antenna** where it is radiated into space, and a receiving system for picking up part of this radiated energy and converting it into an audible or visual reproduction of the original dots and dashes. Practically all present day radio telegraph circuits employ **continuous waves.**

At the lower radio frequencies the alternating currents can be generated by special rotating machines, such as the Alexanderson alternator, and in fact were so generated at first. Now nearly all radio signals are generated by vacuum-tube circuits so we shall confine this discussion to them. Regardless of the size or rating of the transmitting station, the high-frequency a-c originates in the **oscillator.** In the simplest transmitters the output of the oscillator may be connected directly to the antenna but usually this oscillator output feeds an **amplifier** stage or stages

where the power is built up by the amplifying action of vacuum **tubes** and their associated circuits. Not only is the power increased beyond that which can satisfactorily be obtained from oscillators directly, but the character of the transmitted signal is improved. The frequency of an oscillator varies with the voltage, with the load, etc., so by using a **buffer** amplifier the frequency **stability** of the station is improved and this is reflected in more reliable reception and decreased interference between stations. Where it is necessary to operate over a considerable range of frequencies the oscillator is self-controlled, i.e., its frequency may be varied by varying the tuning control just as is done in the familiar broadcast **receiver,** while for fixed-frequency operation the oscillator is preferably **crystal**-controlled. Often where only a few fixed operating frequencies are needed the oscillator is still crystal-controlled with several crystals which may be cut in by a selector

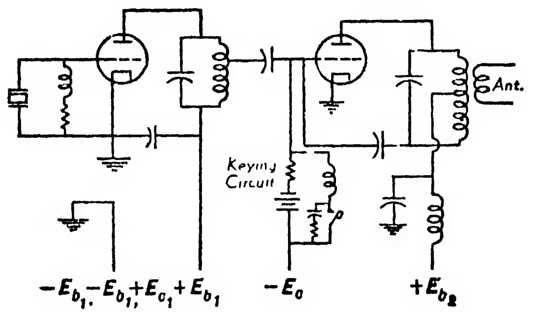


Fig. 1. Simple radio telegraph transmitter

switch. A simple radio telegraph transmitter is shown in Fig. 1. Not only must the transmitter generate the necessary a-c power for the antenna but suitable means for interrupting this to produce the dots and dashes of the code must be incorporated. While it is necessary in some types of service to stop the oscillation completely for spaces and hence becomes necessary to key in the oscillator, this produces some frequency drift and often an undesirable chirpy signal unless extreme care is taken in the design and operation of the transmitter. As a consequence of this effect on the output signal, the keying is often done in one of the amplifier stages, the oscillator operating continuously but the keyed amplifier preventing the signals from reaching the antenna. The radio-frequency energy is radiated into space by the antenna, the exact spatial distribution depending upon the antenna system which is often designed for the particular type of service. Many telegraph stations employ **directional antennae** as most of their work is with fixed stations and does not require general coverage.

The receiving antenna intercepts the radio wave and hence has a very small voltage induced in it. This voltage is fed into the receiver which involves some sort of selective circuit for tuning in the desired station, usually one or more stages of amplification, a **detector** and an audio **amplifier.** The reception of continuous wave signals by ear requires some means of converting the high radio frequencies into an audible frequency. This is accomplished by heterodyning the incoming signal with a slightly different frequency of locally generated a-c to produce an audible beat. This beat, upon **detection,** becomes an **audio-frequency** current which can operate the diaphragm of the headphones or **speaker** to give a sound. This, of course, responds to the keying of the original radio wave. (See **heterodyne** and **detection.**) Fig. 2 shows the wave forms produced in this detection process.

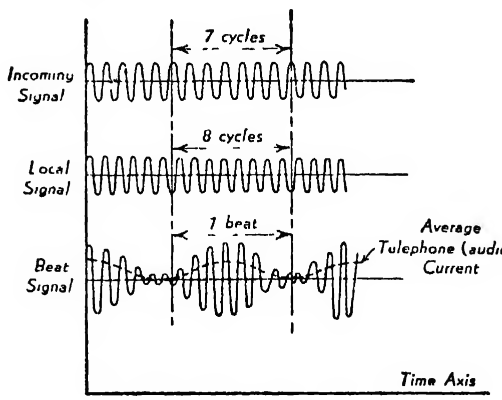


Fig. 2

The simplest form of vacuum-tube **receiver** for this type action is the regenerative detector which serves as an oscillator and detector at the same time. The output may be fed directly into phones. However, this has minor commercial application, much more elaborate circuits being used in modern commercial receivers. Even where the regenerative detector is used it is usually preceded by a stage or two of tuned radio-frequency amplification and followed by one or more audio amplifier stages. Such a receiver is shown in Fig. 3. The various tuned circuits are ad-

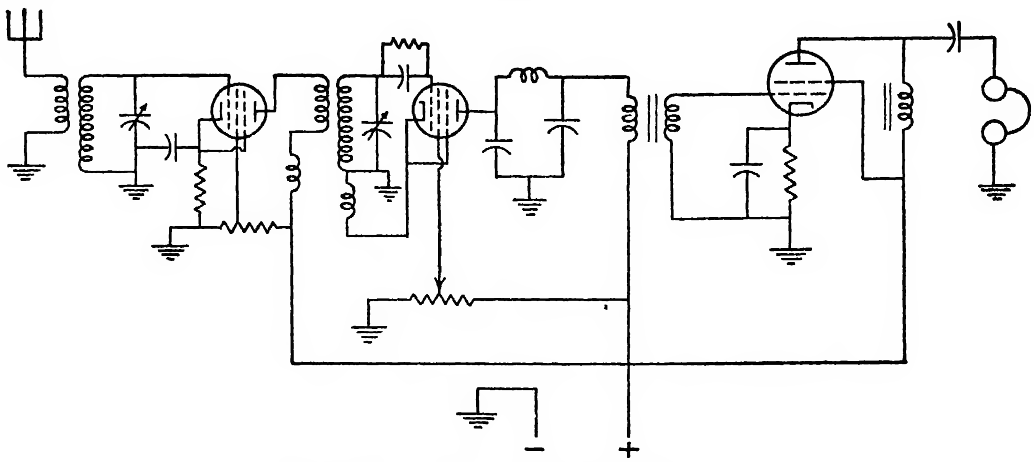


Fig. 3 Commercial radio telegraph receiver

justed so their response is a maximum at the frequency of the station desired. This gives the needed selectivity. After detection the audio signal is built up by the amplifiers to drive a head-set or speaker. Much of the present day reception is done with **super-heterodyne** receivers, a beat-frequency oscillator being added to the basic circuit. This oscillator is fix-tuned to the intermediate frequency plus, let us say, 1000 cycles and its output mixed with the intermediate frequency output at the detector. The result is the 1000-cycle beat note. Other refinements include crystal filter circuits to cut out interference from stations on almost the same frequency as the desired one.

Manual operation of the radio telegraph employing a hand-operated key at the transmitting end and earphones at the receiver, is satisfactory for a great many services. However, there are instances where limitations in speed of transmission of messages, caused by the inability of even trained and competent operators to receive more than approximately 40 words per min, do not fully develop the possibilities of either the investment or of the channel allotment. Particularly, in point-to-point commercial wireless telegraphy automatic transmitting and receiving equipment is justified. In one system the message is typed out on a machine having a keyboard similar to a standard typewriter. Operation of this machine perforates a roll of paper which is then fed into an automatic transmitter, in which the perforations in the tape create an action which takes the place of the manual keying of the hand-operated transmitter. Since the perforation of the tape and its use occur in two different machines there need not be any equality of the speed of perforating the roll and the speed with which it is then fed through the automatic transmitter. Several perforating machines might be employed to supply messages to one automatic transmitter, so the limitations imposed by an operator's speed of typing need not affect the transmitter. As a result, the latter can be made to transmit over 200 words per min. This greatly increases the use to which a point-to-point wireless telegraph system may be put. Naturally, reception of such high-speed signals must also be the function of a machine. A commonly used system has an ink recorder in which movement of the pen is controlled by the incoming signal, and a record of dots and dashes is made upon a continuous roll of paper. Operators may then transcribe this ink record into the original message.

RADIO-THERMOLUMINESCENCE. Luminescence exhibited by certain substances as a result of irradiation by β- and γ-rays, followed by heating.

RADIO TRANSMITTER. See **transmitter, radio.**

RADIOTHORIUM. A **thorium** isotope of mass number 228, produced naturally by β-decay of actinium 228 (mesothorium II). Radiothorium emits α-particles (half-period 1.90 years) to give radium 224 (thorium X).

RADIO WAVE PROPAGATION. The transfer of energy by electromagnetic radia-

tion at frequencies lower than about 3×10^{12} cycles per second.

RADIUM. Radioactive element. Symbol Ra. Atomic number 88.

RADIUS, FOCAL. See **ellipse; hyperbola.**

RADIUS OF GYRATION. The radius of gyration of a mass in respect to a particular axis is the square root of the quotient of the moment of inertia divided by the mass. It is the distance at which the entire mass must be assumed to be concentrated in order that the product of the mass and the square of this distance will equal the moment of inertia of the actual mass about the given axis. The numerical value of the radius of gyration, k, is given by the following formula in which I is the moment of inertia and M, the mass

$$k = \sqrt{\frac{I}{M}}.$$

The radius of gyration of an area is similar except that the moment of inertia of the area is involved. (See **inertia, products and moments of.**)

RADIUS OF THE UNIVERSE. The length $R = cT$ where $T = 5 \times 10^9$ years is the reciprocal of the **Hubble constant.** R is thus of order 10^{27} cm In some **cosmological models,** R is approximately the mean radius of curvature of the universe.

RADIX (OR BASE) (OF THE POSITIONAL NOTATION SYSTEM OF NUMBERS). The integer of whose successive powers the digits of a number are the coefficients. Symbolically:

$$\cdots + a_2r^2 + a_1r + a_0r^0 + a_{-1}r^{-1} + a_{-2}r^{-2} \cdots$$

is written

$$\cdots a_2a_1a_0 . a_{-1}a_{-2} \cdots$$

where r is the radix and the a_i are the integers $0 \leq a_i \leq r - 1$. For example, in the number π written in the common decimal system, we have:

$$r = 10; \quad \cdots a_2 = a_1 = 0; \quad a_0 = 3;$$
$$a_{-1} = 1; \quad a_{-2} = 4 \cdots.$$

RADIX POINT. The index which separates the digits associated with negative powers from those associated with the zero and positive powers of the base of the number system in which a quantity is represented. For example, **binary point, decimal point.**

RADOME. A dielectric housing for an **antenna.**

RADON. Radioactive gaseous element, for which the name emanation is also used. Symbol Rn. Atomic number 86.

RAIES ULTIMES. See **persistent spectrum.**

RAIN. Liquid water drops ranging in diameter from 0.5 mm to approximately 5.0 mm, usually falling with velocities ranging from 3 m per sec to 8 m per sec. Rain is the most common type of precipitation.

RAINBOW. Looking into a spray or mist which is illuminated by strong white light from behind his own back, an observer sees one and sometimes two sets of concentric, spectrally colored rings, called a rainbow. If two are visible, the inner, called the "primary bow," is brighter and narrower than the outer or "secondary bow." In the primary, the red is on the outside edge and violet on the inside; the order in the secondary being the reverse of this The colors are not so pure as in a **spectrum,** because each wavelength extends over a wide radial range, the rainbow itself being made up of the fairly pronounced intensity maxima.

The colors of the rainbow are caused by the refractive **dispersion** of the spherical water drops. Figs. 1 and 2 show, respectively, the

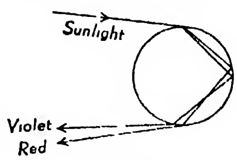


Fig. 1

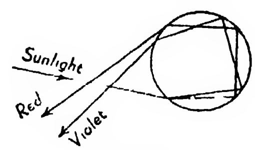


Fig 2

Formation of primary bow (left) and secondary bow (right). Circles represent raindrops

dispersion composing the primary and the secondary bow. The figures also explain why the order of colors is reversed, and show that only the highest drops in the primary and the lowest in the secondary refract red light to the eye. The two internal reflections, with consequently greater loss of light, explain why the secondary bow is fainter. The center of the ring system is exactly opposite the source of light; so that natural rainbows are seen only when the sun is near the horizon,

unless the observer is elevated high above the surrounding country and can look obliquely downward into the rain.

RAMAN EFFECT. A phenomenon involved in the **scattering** of light from the molecules of transparent gases, liquids, and solids; discovered by the Indian physicist, C. V. Raman, in 1928. It consists in the appearance of extra spectrum lines in the vicinity of each prominent line of the spectrum of the incident light. For example, if light from a mercury arc shines into carbon tetrachloride (CCl_4, a liquid), some of the violet lines in the scattered light, especially the one at 4358 angstroms, have associated with them a fairly distinct "Raman spectrum," consisting of several lines, some of which are of longer, some shorter, wavelength than the much brighter, unaltered line. The shorter, usually faint lines, are called **"anti-Stokes" lines.** The Raman spectrum for a given line is characteristic of the scattering substance, and is made up of lines somewhat more diffuse, or "broader," than the corresponding incident line. Water gives broad bands. The phenomenon extends into the x-ray region, and is somewhat analogous to the **Compton effect,** in which, however, the scattering particles are electrons instead of molecules. The Raman effect is explained as being a change in frequency of the incident radiation due to a change in rotational or vibrational energy of the scattering molecules. It is, therefore, useful in studying molecular structure and behavior.

RAMSAUER EFFECT. A beam of electrons with energies below a certain critical value is attenuated very little on passage through any of the inert gases. Through other substances, the absorption of slowly-moving electrons is normal.

RAMSAY AND SHIELDS MODIFICATION OF EÖTVÖS EQUATION. Ramsay and Shields found that at temperatures not too near the critical point the molar **surface energy** could be expressed in the form:

$$\gamma(Mv)^{2/3} = k(t_c - t - 6)$$

where γ is the surface tension of a liquid and v is its specific volume, both at temperature t, M is its molecular weight, t_c is its critical temperature, and k is a constant.

RAMSAY-YOUNG RULE. An empirically derived relationship between two sets of temperatures at which two chemically-similar liquids have the same **vapor pressures** of the form:

$$T_1/T_2 = T_1'/T_2'$$

in which T_1 and T_2 are temperatures at which two similar liquids have the same vapor pressure P, and T_1' and T_2' are temperatures at which the substances have the same vapor pressure P'. This relationship is useful in comparing vapor pressures at different temperatures, and boiling points at different pressures, of similar compounds.

RAMSDEN CIRCLE. If a telescope is focused for infinity, and pointed toward a bright sky, while a sheet of white paper is held near the eyepiece, a sharp, bright circle of light (the exit pupil), called the Ramsden circle can be found. The diameter of this circle divided into the diameter of the **objective lens** gives the **magnification** of the telescope.

RAMSDEN EYEPIECE. See **eyepiece, Ramsden.**

RANDOM COINCIDENCE. See **coincidence.**

RANGE. (1) The distance that a particle will penetrate a given substance before its kinetic energy is reduced to a value below which it can no longer produce ionization. For a heavy ion, such as a **proton** or an **α-particle,** the range usually refers to the component of displacement in the initial direction; it is only slightly shorter than the path length, or distance measured along the track of the particle. For a **meson,** whose track shows moderate deflections near the end, the range usually refers to the path length. For an electron, whose track may be quite tortuous because of frequent deflections, the range usually refers to the greatest distance of penetration in a specified direction; this distance may be considerably shorter than the path length. The residual range is the distance over which the particle can still produce ionization after having already lost some of its energy in passing through matter. Because of the phenomenon of **straggling,** particles of a given kind and of the same initial energy do not all have the same range. For heavy ions, the ranges are distributed, in a manner

similar to the normal probability distribution, about the mean range, or range that is exceeded by half of the particles. The extrapolated range is the intercept on the range axis of a straight line drawn through the descending portion of a numbers-versus-range curve for initially monoenergetic particles; it exceeds the mean range by a few per cent. The maximum range for a group of ionizing particles is the greatest distance in a specified direction at which their ionization can be detected. The linear range is the range expressed in units of length. The mass range is the range expressed in units of surface density; it is thus the mass per unit area of a layer of thickness equal to the linear range, and is equal to the product of the linear range and the density of the substance. (See **Bragg curve.**) (2) In ballistics, the horizontal component of the displacement of a projectile before it strikes the ground.

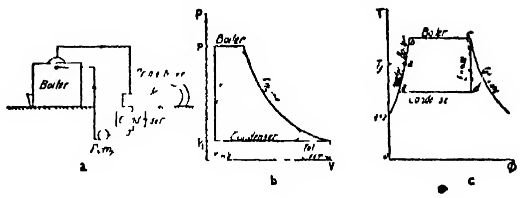
RANGE-ENERGY RELATION. The relation, usually expressed in the form of a graph, between the range of particles of a given type and initial kinetic energy and the energy. For α-particles and similar heavy ions, the range involved is usually the mean range, most commonly in dry air at 15°C and 1 atm. For electrons, it is usually the maximum range, most commonly in aluminum. For β-particles the energy involved is the maximum kinetic energy of the **β-particle spectrum.**

RANGE, VISUAL. The value of the range of β-particles in an absorber, usually aluminum, estimated by visual inspection of breaks in the aluminum absorption curve. (Cf. **Feather analysis.**)

RANK. (1) A **matrix** or **determinant** is of **rank** n if it contains at least one non-vanishing determinant of order n but all of its higher order determinants equal zero. (2) A system of homogeneous **linear equations** is of rank n if the matrix of its coefficients has that rank. (3) When used with reference to **tensors** of dimension m the rank is n if the tensor has m^n components. A tensor of rank zero is a **scalar** or **invariant;** one of rank unity is a **vector.** (4) The number of independent **cut-sets** that can be selected in a **network.** The rank R is equal to the number of **nodes,** V, minus the number of separate parts P. Thus $R = V - P$.

RANKINE APPARATUS FOR GAS VISCOSITY. A capillary tube and a wider tube containing a small pellet of mercury are arranged side by side and connected at top and bottom. The tubes are inverted, and the pellet slides down the wider tube, forcing gas through the lower end of the tube, through the capillary, and back into the upper end of the wider tube. The viscosity is found from the time of fall of the drop between two points, and the radii of the tubes. This is a convenient method for comparing viscosities of different gases, or variation of viscosity with temperature.

RANKINE CYCLE. Rankine's modification of the Carnot cycle is the basis of the modern steam plant cycle even though the Rankine cycle itself has been modified and changed



with the passing of time. The elements of the Rankine vapor cycle are shown in Fig. (a). It consists essentially of a **boiler** which receives **feed water** from a **pump,** a prime mover to expand the steam **adiabatically,** a **condenser** to receive the exhaust steam from the **engine** and reduce it to water, and a pump to overcome the pressure difference between boiler and condenser. Figs. (b) and (c) show this cycle on the pressure-volume and temperature-entropy planes.

RANKINE TEMPERATURE SCALE. A **temperature scale** which corresponds to the Kelvin scale, but is based on the absolute zero of the Fahrenheit system, so that 0° Rankine = −459.69°F.

RAOULT LAW. The **vapor pressure** of a **solution** is given by

$$p = p_0 x$$

where p_0 is the vapor pressure of the pure solvent, and x is the **mole fraction** of solvent.

RAPHAEL BRIDGE. A form of **Wheatstone bridge** used to determine the position of a fault on a telephone line or cable.

RARE EARTH. An oxide of one of the rare earth metals (see **element, rare earth**) or a mixture of such oxides.

RAREFACTION, ACOUSTIC. The local decrease in density due to a passing sound wave.

RAST METHOD. See **freezing point depression measurement.**

RASTER. In television, a predetermined pattern of **scanning lines** which provides substantially uniform coverage of an area.

RAT RACE. A **hybrid ring.**

RATE OF DECAY OF SOUND. The time rate at which the **sound pressure level** (or **velocity level,** or **sound-energy density level**) is decreasing at a given point and at a given time. The practical unit is the **decibel** per second.

RATING, CONTINUOUS-DUTY. The rating applying to operation for an indefinitely long time.

RATING, INTERMITTENT-DUTY. The specified output rating of a device when operated for specified intervals of time other than continuous duty.

RATIO. The indicated **quotient** of two numbers frequently expressed as a **fraction** and written as $a:b$, a/b, or $a \div b$. (See also **proportion.**)

RATIO DETECTOR. See **detector, balanced.**

RATIONAL. Applied to an expression which involves the **variable** in only the rational operations of addition, subtraction, multiplication, division, and raising to powers with constant integral exponents. Rational functions are divided into two sub-classes: rational integral functions or **polynomial functions,** and rational **fractional functions.**

RATIONAL ACTIVITY COEFFICIENT. The **activity coefficient** derived from the **Debye-Hückel theory** of electrolytes.

RAY. The direction of propagation of **electromagnetic waves;** a line constantly perpendicular to the wave fronts. Rays are straight lines in homogeneous media, but may be bent at interfaces between different media, and curved in non-homogeneous media. Even a sufficiently-intense **gravitational field** may bend rays slightly.

RAY ACOUSTICS. The analysis of acoustical problems under the assumption that sound travels along straight lines or rays in passing through homogeneous material. **Diffraction** effects are neglected. The methods of ray acoustics are applicable only if the state of the medium and the boundaries of the medium change only slightly over a distance equal to the sound wavelength.

RAY, ACTINIC. A misnomer for **actinic radiation,** i.e., for radiation, particularly in the ultraviolet, having pronounced chemical or biological effects.

RAY, ALPHA. See **α-rays.**

RAY, BETA. See **β-rays.**

RAY, BECQUEREL. See **Becquerel rays.**

RAY, CANAL. See **canal rays.**

RAY, CATHODE. See **cathode rays.**

RAY, CHIEF. See **chief ray.**

RAY, COSMIC. See **cosmic rays.**

RAY, EXTRAORDINARY. See discussion of **ray, ordinary,** and of **double refraction.**

RAY, GAMMA. See **λ-rays.**

RAY, INFRARED. A misnomer for infrared radiation (see **radiation, infrared**), i.e., for electromagnetic waves in the wavelength region 0.78 to 300 microns. (The upper limit is often considered to be as high as 1000 microns.)

RAY, ORDINARY. When light is incident obliquely on an **anisotropic crystal** or other double-refracting medium and is split into two components, the ray which is deviated at an index of refraction independent of the **angle of incidence** is the ordinary ray. The other ray, the extraordinary ray, has an index of refraction that varies with the angle of incidence.

RAY(S), PARALLEL. Rays from a very distant point reach an optical system as parallel rays: Hence any bundle of rays parallel to each other, and, particularly, parallel to the optical axis of an optical system.

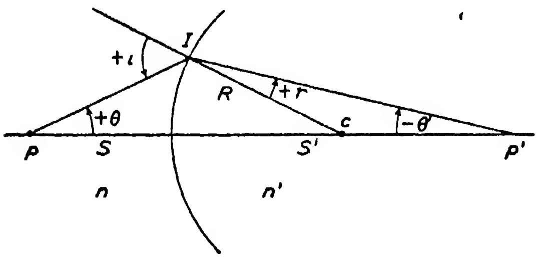
RAY(S), PARAXIAL. Rays sufficiently close to parallelism with the optical axis of a sys-

tem that, for the purposes of the computation being made, the angles between the rays and the optical axis are so small that sin θ may be replaced by θ.

RAY, ROENTGEN. See **x-rays.**

RAY(S), SKEW. Rays that are not confined to a **meridian plane** do not intersect the optical axis, and are difficult to trace.

RAY TRACING. It is not practicable to set up completely accurate equations to describe an image in terms of the object and optical surface. However, it is possible to trace a ray from a point on an object through an optical system which has only spherical (or plane) interfaces, with complete accuracy.



For rays from a point on the optical axis, the four conventional equations are

$$\sin \iota = \frac{R + S}{R} \sin \theta$$

$$\sin r = \frac{n}{n'} \sin i$$

$$\theta' = r + \theta - i$$

$$S' = R - R \frac{\sin r}{\sin \theta'}.$$

(See also **sign convention (lenses and mirrors)**.)

More complicated methods are needed for skew rays (see **rays, skew**).

RAY, ULTRAVIOLET. A misnomer for ultraviolet radiation (see **radiation, ultraviolet**) in the wavelength band between x-rays and violet visible light.

RAYLEIGH CRITERION OF RESOLVING POWER. The image of a **point object** as seen by any optical system is a **diffraction** pattern. The images are commonly said to be resolved when the principal maximum of one pattern falls on the first minimum of the other pattern. For circular optics, this occurs when the **angular separation** of the point objects as seen from the objective lens of the system is

$$\phi = \frac{1.22\lambda}{a}.$$

Here λ is the wavelength of the light and a is the diameter of the objective lens. (See Robertson, *Introduction to Optics*, Fourth Ed., pages 207 ff.)

RAYLEIGH DISK. A special form of acoustic radiometer (see **radiometer, acoustic**) which is used for the fundamental measurement of particle velocity. (See **velocity, particle.**)

RAYLEIGH DISTILLATION. A simple distillation, wherein the composition of the residue changes continuously during the course of the distillation By analogy, any process which follows the same mathematical relationship.

RAYLEIGH GENERAL PRINCIPLE OF RECIPROCITY. See **reciprocity theorem.**

RAYLEIGH-JEANS EQUATION. From the standpoint of statistical mechanics, using the theorem of the equipartition of energy, Rayleigh and Jeans obtained

$$dE_\lambda = 2\pi ckT\lambda^{-4}d\lambda$$

for the spectral distribution of the radiation from a black body. This formula agrees with experiment only at long wavelengths, and fails completely at short wavelengths. (See the **Planck distribution formula** for the true spectral distribution)

RAYLEIGH LAW. For small magnetization, the **induction** may be approximated by

$$B = \mu_0 H + \nu H^2 + \cdots$$

yielding

$$\mu = \mu_0 + \nu H$$

where μ is the normal permeability, and μ_0 the initial permeability. (See **permeability, normal** and **permeability, initial.**)

RAYLEIGH LAW OF SCATTERING. See discussion of **scattering, Rayleigh.**

RAYLEIGH LINE. That component of a spectrum line in scattered radiation which has

the same frequency as the corresponding incident radiation, arising simply from ordinary or **Rayleigh scattering,** not from the **Compton** or the **Raman effect.**

RAYLEIGH LOOP. A parabolic approximation to the **hysteresis loop**

$$B = (\mu_0 + \nu H_m)H \pm (\nu/2)(H_m^2 - H^2)$$

where $H = \pm H_m$ at the tips of the loop. (See also the **Rayleigh law.**)

RAYLEIGH NUMBER. The quantity $\mathfrak{R}$ defined for the fluid-filled space between two parallel horizontal planes as

$$\mathfrak{R} = \frac{\alpha(\theta_1 - \theta_2)gd^3}{\nu k},$$

where α is the coefficient of thermal expansion of the fluid, $\theta_1 - \theta_2$ is the difference of temperature between the bottom plane and the top plane, g is the acceleration due to gravity, d is the separation of the planes, ν is the kinematic viscosity, k is the thermal conductivity. Convection currents appear only when the Rayleigh number exceeds a critical value. For rigid planes, the critical Rayleigh number is of order 1700

RAYLEIGH RADIATION LAW. See **Rayleigh-Jeans equation.**

RAYLEIGH REFRACTOMETER. See **refractometer, Rayleigh.**

RAYLEIGH-RITZ METHOD. Variational principle for the solution of the eigenvalue equation $A\psi = \lambda B\psi$ (A, B operators) based on taking as a trial function a linear combination of a complete set of functions, with coefficients which are to be varied to give the correct solution.

RAYLEIGH SCATTERING. See **scattering, Rayleigh.**

RC CONSTANT. See **time constant.**

RC COUPLING. See **amplifier.**

RCM. Abbreviation for radar counter measures.

R-C OSCILLATOR. See **oscillator, R-C.**

RDF. Abbreviation for radio **direction-finding** or radiolocation (British).

REACTANCE. The imaginary part of **impedance.** Thus if $Z = R + jX$, the reactance is X.

REACTANCE, ACOUSTIC. The imaginary component of the acoustic impedance (see **impedance, acoustic**). The commonly used unit is the **acoustical ohm.**

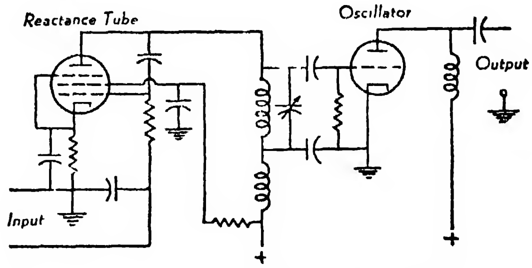
REACTANCE, INTRINSIC ($\mathfrak{X}$). The imaginary part of intrinsic impedance. (See **impedance, intrinsic.**)

REACTANCE, MECHANICAL. The imaginary part of the **mechanical impedance.** The unit is the mechanical ohm.

REACTANCE MODULATOR. See **modulator, reactance.**

REACTANCE, SPECIFIC ACOUSTIC. The imaginary component of the specific acoustic impedance. (See **impedance, specific acoustic.**)

REACTANCE TUBE. A vacuum **tube** operated in such a way that it presents the characteristics of a reactance to the rest of the circuit. As reactance takes a current which is essentially 90° out of phase with the voltage it is necessary that the tube do the same.



Reference to the circuit will indicate one method of connecting it to accomplish this. The **grid** is excited by a voltage obtained from the plate voltage by the resistance-condenser circuit (the condenser connected to the cathode is merely a d-c blocking condenser and is a value which produces no other appreciable effect). The resistance-condenser circuit applies a voltage to the grid which is nearly 90° out of phase with the plate voltage. Since, in a pentode, the plate current is in phase with the grid voltage, this means that the plate current (a-c component) is 90° out of phase with the plate voltage, thus the plate circuit has the desired reactance characteristics. The advantage of the tube over a conventional

reactance is that the magnitude of its reactance effect may be easily varied by adjusting the d-c bias applied to the grid. The circuit shows the tube connected as part of the tuning capacity of an **oscillator.** By varying the grid bias (hence the gain) of the tube the tuning of the oscillator is varied. This is used in many frequency-**modulation** transmitters to give the frequency modulation In this application a suitable audio signal is fed to the grid of the reactance tube so its reactance effect will vary with the audio and hence frequency modulate the oscillator. It is also used in frequency-stabilizing circuits where the deviation from the desired frequency is made to vary the grid bias of the reactance tube and hence correct the oscillator frequency.

REACTION. (1) In general, a response such as the equal and opposite force which, according to the **Newton Third Law of Motion,** results when a force is applied to a material system. Specifically, the force exerted by the supports or bearings on a loaded mechanical system. (2) A term sometimes used for regeneration (see **feedback, positive**). (3) A chemical change. Specifically, a change by which one or more substances are transformed into one or more entirely new substances, the process being accompanied by a change in energy, but not, in most cases, by a change in the total mass of the system. Radioactive reactions, however, both natural and artificial, do involve a change of the mass of the system, which is accompanied by a release of energy, opposite in sign to the change in mass, and equal to its magnitude multiplied by the square of the velocity of light.

REACTION ENERGY, NUCLEAR. (1) The **disintegration energy** of a **nuclear reaction;** symbol Q. It is equal to the sum of the kinetic or radiant energies of the reactants minus the sum of the kinetic or radiant energies of the products. (If any product of a specified reaction is in an excited nuclear state, the energy of subsequently emitted γ-radiation is not included in the sum.) (2) Often, implicitly, the ground-state nuclear reaction energy, which is the reaction energy when all reactant and product nuclei are in their ground states, symbol Q_0.

REACTIVATION OF A FILAMENT. As applied generally to the thoriated-tungsten **filament,** the process consists of applying higher than rated filament voltage for a short period, in order to create a fresh layer of thorium on the emitting surface.

REACTIVITY (NUCLEAR REACTOR). A measure of the departure of a reactor from **critical,** such that positive values of reactivity correspond to reactors above critical and negative values to reactors below critical. Often represented by (a) the **multiplication constant** minus one, (b) a quantity proportional to the **inverse asymptotic period.** Sometimes used interchangeably with the term multiplication constant. (See **inhour**.)

REACTOR. (1) A nuclear reactor is an apparatus in which nuclear fission may be sustained in a self-supporting **chain reaction.** The term reactor may be modified by the words thermal, epithermal, intermediate, or fast to indicate the predominant energy of the neutrons causing fission It may also be modified by the terms heterogeneous or homogeneous to characterize the detailed structure The reactor includes fissionable material (fuel) such as uranium or plutonium, and moderating material (unless it is a fast reactor) and usually includes a reflector to conserve escaping neutrons, provision for heat removal and measuring and control elements. The terms pile and reactor have been used interchangeably, with reactor now becoming more common They usually are applied only to systems in which the reaction proceeds at a controlled rate, but they also have been applied to bombs. Reactors sometimes are designated according to the moderator used (e.g., graphite or beryllium reactor), or coolant (e.g., gas-cooled, liquid metal cooled). (See **fuel; moderator; reflector.**) (2) A device the primary purpose of which is to introduce **reactance** into a circuit. E.g., a **capacitor (electrical)** or a **choke coil.**

REACTOR, BARE HOMOGENEOUS THERMAL. A nuclear **reactor** in which the fissions are induced by thermal neutrons, the fuel being homogeneously distributed throughout the **moderator,** with no **reflector.**

REACTOR, CRITICAL ASSEMBLY OF. An assembly of **moderator** and fuel which is either subcritical or just **critical,** used to study the properties of system and to determine **critical size,** etc.

REACTOR, CRITICAL THICKNESS OF INFINITE SLAB. The thickness which makes the geometric buckling (see **buckling, geometric**) equal to the material buckling. (See **buckling, material.**)

REACTOR, EXPERIMENTAL BREEDER (EBR). A fast heterogeneous **reactor** used for research and breeding. Its core consists of enriched U^{235} surrounded by a "blanket" of natural uranium.

REACTOR, HETEROGENEOUS. A nuclear **reactor** in which the **fuel** is distributed through the **moderator** (or vice versa) in the form of discrete lumps.

REACTOR, HOMOGENEOUS. A nuclear **reactor** in which the fissionable material and **moderator** (if used) are combined in a mixture such that an effectively-homogeneous medium is presented to the neutrons. Such a mixture is represented either by a solution of fuel in moderator, or by discrete particles having dimensions small in comparison with the **neutron mean free path.** (Cf. **reactor, heterogeneous.**)

REACTOR(S), IMAGE. If the method of **images** is used in solving the criticality equations for a nuclear **reactor,** the mathematically introduced new reactors are called image reactors.

REACTOR, INTERMEDIATE. A nuclear **reactor** in which **fission** is induced predominantly by neutrons with energies greater than thermal but less than those of fission neutrons.

REACTOR, LIQUID METAL FUEL (LMFR). A proposed **reactor** which would use a solution of uranium in liquid bismuth as fuel. In one version the fuel would be circulated through a graphite structure which would supply the **moderation.**

REACTOR, MATERIALS TESTING. A nuclear **reactor** designed for the purpose of testing materials and equipment under high radiation fields.

REACTOR, MULTI-GROUP TREATMENT OF. A treatment of nuclear **reactor** theory in which the neutron energy spectrum is considered as being made up of a number of energy groups.

REACTOR, ONE-GROUP THEORY OF. A treatment of nuclear **reactor** theory in which it is assumed that the production, diffusion, and absorption of neutrons occur at a single energy, the thermal energy.

REACTOR(S), PERTURBATION THEORY APPLIED TO. The effect of changes in a nuclear **reactor** structure resulting, for example, from localized **poisons** or temperature changes may be determined by means of **perturbation theory.**

REACTOR, POWER. A nuclear **reactor** designed principally for the economical production of power.

REACTOR, PRESSURIZED WATER (PWR). A power reactor (see **reactor, power**) using slightly enriched uranium as fuel. Water under high pressure is the moderator and coolant.

REACTOR, PRODUCTION (REGENERATIVE). A nuclear **reactor** designed principally for the production of fissionable material, usually Pu^{239}.

REACTOR, REFLECTOR SAVINGS OF. The decrease in the critical size of a half-dimension (e.g., half-thickness of a slab) in a nuclear **reactor** due to a reflector.

REACTOR, SIMPLE. A linear reactor (see **reactor (2)**) usually inductive.

REACTOR, SUBMARINE INTERMEDIATE. A nuclear **reactor** designed for the production of power to be used in propelling a naval vessel, and utilizing neutrons of intermediate velocity.

REACTOR, SUBMARINE THERMAL. A nuclear **reactor** designed for the production of power to be used in propelling a naval vessel, and utilizing thermal neutrons.

REACTOR, SWIMMING POOL. A thermal, heterogeneous, light-water moderated **reactor** used for research. The fuel elements are plates of an alloy of uranium-235 and aluminum, encased in aluminum.

REACTOR SYSTEM, CRITICAL STATE OF. The state in which just as many **neutrons** are being produced by **fission** as are lost by absorption and leakage.

REACTOR, TWO-GROUP THEORY. A treatment of nuclear **reactor** theory in which it is assumed that the neutrons are at two energies, fast and thermal. (See **neutrons, fast** and **neutrons, thermal.**)

REACTOR(S), TYPES OF. Nuclear reactors are classified according to the type of enrichment of the fuel, energy of the fissioning neutrons, type of **moderator** (if **thermal**), arrangement of the fuel (homogeneous or heterogeneous) and purpose. Thus a reactor might be described as a natural uranium, thermal, graphite-moderated, heterogeneous, research reactor. Often the power level and thermal neutron flux are also given.

REACTOR, WATER BOILER. A homogeneous thermal **reactor** which utilizes enriched uranium as fuel and ordinary water as moderator, the fuel being in the form of a solution of uranium sulfate in the water.

RECALESCENCE. A singular phenomenon exhibited by iron and some other ferromagnetic metals. If iron is heated white hot and allowed to cool, it will, at a certain temperature, suddenly evolve enough heat to halt the cooling and even produce a momentary heating. This is easily exhibited by stretching an iron wire against the tension of a spring and arranging a lever index to show slight changes in length The wire is first heated by an electric current. As it cools and contracts, the index will at a certain point give a perceptible jerk, and then resume its steady motion of contraction. The effect is due to an exothermic change in the crystalline structure. The reverse phenomenon, exhibited on heating, is called "decalescence" For cast iron the recalescence point is a little below 700°C. Pure iron has two such points, at 780°C and 880°C.

A somewhat analogous effect is exhibited by some amorphous solids upon **devitrification,** which takes place when the temperature becomes high enough for the substance to crystallize. Non-crystalline sodium silicate, for example, has such a transition point near 500°C, where it suddenly begins to glow.

RECALESCENT POINT. See **recalescence.**

RECEIVER. See (1) **earphone;** (2) **receiver (radio).**

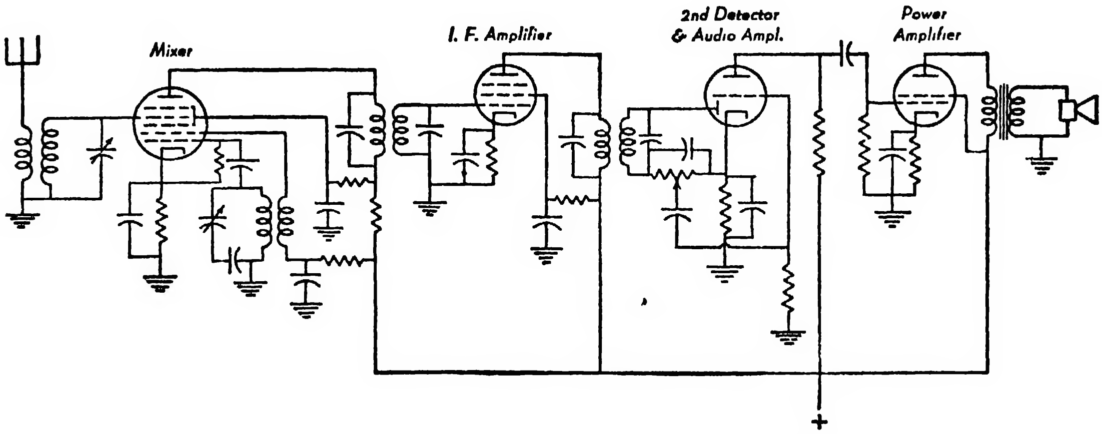
RECEIVER, DUAL-DIVERSITY. A diversity receiving system (see **reception, diversity**) which, instead of mixing the signals from the two or more antenna-receiver systems, has an automatic selection system which connects the output to the receiver having the stronger signal.

RECEIVER, PANORAMIC. A **receiver** which is periodically tuned through a certain band of frequencies. The receiver output, displayed on a **cathode-ray tube** whose time base is synchronized with the receiver tuning rate, indicates all signals and their amplitudes within the swept band. In the microwave frequencies, this is sometimes called a **spectrum analyzer.**

RECEIVER PRIMARIES. The colors of constant **chromaticity** and variable **luminance** produced by a television receiver which, when mixed in proper proportions, are used to produce other colors. Usually three primaries are used: red, green, and blue

RECEIVER PULSE DELAY. See **transducer pulse delay.**

RECEIVER, RADIO. The radio receiver is the device which picks up the wave from the transmitter and converts it to sound The simplest form of practical receiver is the crystal set which was once used extensively, then with the advent of satisfactory and cheap vacuum-tube circuits was largely discarded, and which is now coming back as a receiver for ultra high and super high frequencies Such a set consists of some means of selecting or tuning the desired signal, a rectifying type crystal (galena, silicon, etc.) as a **detector** and a head-set. In its present application for the extremely high frequencies the tuning elements are **lines** and **wave guides.** In the early days of broadcasting the regenerative receiver was almost universally used. However, it has serious limitations, chief among them being its poor audio quality and its radiating ability. As a consequence it is no longer used for regular broadcast reception and its present use is confined to the reception of continuous wave signals, as in radio telegraphy. Tuned radio-frequency receivers were also widely used at one time but are not used much except in the cheaper broadcast receivers and in some long wave commercial stations. This receiver has an antenna-coupling circuit for tuning and coupling the **antenna** to the **grid** of the first amplifier **tube.** This tube may be coupled by a second tuned circuit to another **amplifier**



Simplified-circuit diagram of superheterodyne receiver

or in smaller sets it may be coupled to the **detector.** Each coupling circuit up to the grid of the detector is tuned and for home receivers the present-day sets have all tuning elements controlled by a single dial. Early sets had each element controlled by a separate dial. While the detector may be any of the conventional types it is usually a triode biased almost to cut-off This produces rectification and hence demodulation of the radio signal. The audio output of the detector is then amplified by one or more audio-amplifier stages and fed to the **speaker** where it is converted to sound.

The superheterodyne receiving circuit differs from others in that it converts all incoming radio-frequency signals to a common carrier frequency. This is accomplished in the first detector, mixer or converter as it is variously called. The signal from the antenna is fed by a tuned coupled circuit to the mixer tube (or in more elaborate sets a tuned radio-frequency stage may be inserted between the antenna and the mixer). In the mixer stage the incoming signal is heterodyned with a locally generated signal so a beat frequency signal, called the intermediate frequency, is produced. This new frequency signal is radio frequency, ranging from around 450 kc to several megacycles depending upon the purpose for which the receiver is designed. The intermediate frequency has exactly the same modulation as the original signal. In many broadcast receivers the mixer tube combines the functions of mixer and oscillator by using a multiplicity of grids (the **pentagrid converter** is an example of such a tube). However, at higher frequencies it is desirable or even necessary to use a separate tube for **oscillator** and feed its output into the mixer, Regardless of how the oscillator operates, its frequency is always adjusted by the main tuning control of the receiver so the beat frequency output of the mixer is a fixed value. This intermediate frequency signal is then amplified by fixed-tuned radio-frequency amplifiers and then fed to the detector (commonly called the second detector) where it is demodulated. The audio is then further amplified and coupled to the speaker. The simplified-circuit diagram will serve to indicate the various circuits and their relative positions. In some of the cheaper superheterodynes the antenna signal is coupled to the pentagrid first detector, then the intermediate frequency output of this coupled without further amplification to a grid bias or regenerative detector and hence to the final power tube. Various refinements are often added to the higher quality sets. Among these are **automatic gain control, automatic frequency control, noise suppression, tone control,** fidelity and selectivity controls, etc. The superheterodyne gives much greater selectivity by its system of frequency changing and also permits the use of circuits having a more uniform response to the **sidebands.**

The development of television has led to extensions of the principles involved in the usual radio receiver but has not required any radically different ones. The main difference between the sound receiver and the picture receiver is in the width of the bands which must be handled, television requiring a band several megacycles wide while sound requires only a few kilocycles. This means that the

radio frequency channels must be capable of selecting between stations yet also pass very wide sidebands. In addition the amplification circuits after the detector (corresponding to the audio amplifiers of the sound set) must satisfactorily amplify over a range of a few million cycles. Frequency **modulation,** on the other hand, has necessitated the use of a somewhat different type of detector. The incoming frequency modulated signal is amplified, converted to the intermediate frequency and this further amplified as in the usual set. However, since the modulation is present as a frequency variation and the loudspeaker responds to an amplitude variation it is necessary to change from one to the other upon detection. This is accomplished in a **discriminator** (a frequency sensitive detector) and then the resulting audio signals, which are amplitude variations, are amplified in a standard audio **amplifier.** However, the radio and intermediate frequency channels of the FM set must be fairly wide band (about 200 kc) and the audio must be good to about 15,000 cycles to realize the full benefits of this type modulation.

Besides these basic circuit distinctions radios are often classified according to the type **power supply** used. Thus battery receivers for rural and portable use, a-c sets for operating from the 110-volt a-c house-supply circuit, a-c–d-c sets for use with either 110 (nominal) volts a-c or d-c, etc., are among the various types available.

RECEIVER, RADIOTELEGRAPH. A radio receiver (see **receiver, radio**) designed for the reception of radiotelegraph signals. Distinctive characteristics include very slow AGC action, peaked audioresponse to suppress noise and interfering signals, and some form of beat-frequency oscillator required to make the transmission audible. (See **radio telegraphy.**)

RECEIVER, SINGLE-SIDEBAND. A radio receiver (see **receiver, radio**) designed for the reception of single-sideband modulation. This device differs from other receivers in that it must have provisions for restoring all or a part of the **carrier,** which is partially or totally deleted upon transmission.

RECEIVER, SUPERHETERODYNE. A receiver (see **receiver, radio**) which converts all incoming radio-frequency signals to a common intermediate "carrier" frequency before conversion to the original **modulation.**

RECEIVER, SUPERREGENERATIVE. See **superregenerative receiver.**

RECEIVER, TUNED R.F. A receiver (see **receiver, radio**) in which all amplification before detection is performed at the original frequency of transmission in stages individually tuned for this frequency.

RECEIVING CURRENT SENSITIVITY. See **response, free-field current.**

RECEIVING VOLTAGE SENSITIVITY. See **response, free-field voltage.**

RECEPTION, DIVERSITY. A radio receiver (see **receiver, radio**) system which reduces sensitivity to fading caused by variable propagation characteristics. The system generally consists of two or more antennas located several wavelengths apart, feeding individual receivers whose outputs are combined. While the output of an individual unit may fade with time, experience indicates that the combined output of a properly-designed system will be nearly constant.

RECEPTION, PERIDYNE. See **peridyne reception.**

RECESSION OF NEBULAE. See **Hubble constant.**

RECIPROCAL. Given a number or function a, its **reciprocal** is $1/a$. (See also **matrix, reciprocal; vector system, reciprocal.**)

RECIPROCAL LATTICE. Let $\mathbf{a}$, $\mathbf{b}$, $\mathbf{c}$, be the **primitive translations** of a given crystal lattice. Let

$$\mathbf{a}^* = \frac{\mathbf{b} \times \mathbf{c}}{\mathbf{a}\cdot(\mathbf{b} \times \mathbf{c})}, \quad \mathbf{b}^* = \frac{\mathbf{c} \times \mathbf{a}}{\mathbf{a}\cdot(\mathbf{b} \times \mathbf{c})},$$

$$\mathbf{c}^* = \frac{\mathbf{a} \times \mathbf{b}}{\mathbf{a}\cdot(\mathbf{b} \times \mathbf{c})}.$$

Then $\mathbf{a}^*$, $\mathbf{b}^*$, $\mathbf{c}^*$, define the **unit cell** of the reciprocal lattice. This has the properties (i) the vector $\mathbf{r}^*(hkl) = h\mathbf{a}^* + k\mathbf{b}^* + l\mathbf{c}^*$ of the reciprocal lattice is normal to the (hkl) plane of the crystal lattice, (ii) the length of the vector $\mathbf{r}^*(hkl)$ is equal to the reciprocal of the spacing of the (hkl) planes.

RECIPROCAL TRANSDUCER. See **transducer, reciprocal.**

RECIPROCAL VELOCITY REGION. The energy region (generally from 0 to several ev) in which the capture cross section (see **cross section, capture**) for neutrons by a given element is inversely proportional to the neutron velocity.

RECIPROCITY CALIBRATION. The calibration of a microphone by application of the **reciprocity theorem (acoustical)**, with the use of a reversible microphone-loudspeaker and a separate loudspeaker.

RECIPROCITY LAW (PHOTOGRAPHIC). The **optical density** of an exposed emulsion, with standard development, is a function of only the **irradiance** and time of exposure. This law may be applied only in certain situations.

RECIPROCITY THEOREM, ACOUSTICAL. In an acoustic system comprising a fluid medium having bounding surfaces S_1, S_2, S_3, $\cdots$, and subject to no impressed body forces, if two distributions of normal velocities v_n' and v_n'' of the bounding surfaces produce pressure fields p' and p'', respectively, throughout the region, then the surface integral of $(p''v_n' - p'v_n'')$ over all the bounding surfaces S_1, S_2, S_3, $\cdots$, vanishes. If the region contains only one simple source, the theorem reduces to the form ascribed to Helmholtz; viz., in a region as described, a simple source at A produces the same sound pressure at another point B as would have been produced at A had the source been located at B.

RECIPROCITY THEOREM, ELECTRIC-NETWORK. In an electric network composed of passive bilateral linear impedances, the ratio of an electromotive force introduced in any branch to the current measured in any other branch, called the transfer impedance, is equal in magnitude and phase to the ratio that would be observed if the positions of the electromotive force and the current were interchanged. When altering the location of an electromotive force in a network, the branch into which the electromotive force is to be introduced must be opened, while the branch from which it has been removed must be closed.

RECIPROCITY THEOREM, ELECTROACOUSTICAL. For an electroacoustic **transducer** satisfying the reciprocity principle, the quotient of the magnitude of the ratio of the open-circuit voltage at the output terminals (or the short-circuit output current) of the transducer, when used as a sound receiver, to the free-field sound pressure referred to an arbitrarily selected reference point on or near the transducer, divided by the magnitude of the ratio of the sound pressure apparent at a distance, d, from the reference point to the current flowing at the transducer input terminals (or the voltage applied at the input terminals), when used as a sound emitter, is a constant called the "reciprocity constant" independent of the type or constructional details of the transducer. The reciprocity constant is given by

$$\left|\frac{M_0}{s_0}\right| = \left|\frac{M_s}{s_s}\right| = \frac{2d}{\rho f} \cdot 10^{-7}$$

where M_0 is the free-field voltage response as a sound receiver, in open-circuit volts per **microbar**, referred to the arbitrary reference point on or near the transducer; M_s is the free-field current response in short-circuit amperes per microbar, referred to the arbitrary reference point on or near the transducer; s_0 is the sound pressure produced at a distance d centimeters from the arbitrary reference point in microbars per ampere of input current; s_s is the sound pressure produced at a distance d centimeters from the arbitrary reference point in microbars per volt applied at the input terminals; f is the frequency in cycles per second; ρ is the density of the medium in grams per centimeter^3; d is the distance in centimeters from the arbitrary reference point on or near the transducer to the point at which the sound pressure established by the transducer when emitting is evaluated.

RECOIL, AGGREGATE. See **aggregate recoil.**

RECOIL NUCLEUS. See **nucleus, recoil.**

RECOIL PARTICLE. A particle that has been set into motion by a collision or by a process involving the ejection of another particle. The direction and magnitude of the recoil are determined by the conservation of **momentum.** Examples are **Compton recoil electrons, recoil nuclei** in **α-decay,** and fission fragments.

RECOMBINATION, COEFFICIENT OF. A coefficient A that appears in the law expressing the rate of recombination of ions in

a gas. If n^+ and n^- are the respective numbers per unit volume of the ions of the two signs, then

$$\frac{dn^+}{dt} = \frac{dn^-}{dt} = An^+n^-.$$

The constant depends both on the nature of the gas and on the pressure.

RECOMBINATION, COLUMNAR. Recombination which takes place before the ions have left the track, in the case where the ionization takes place along a column, e g, the case of the dense ionization produced along the track of an α-particle. The magnitude of columnar recombination in an **ionization chamber** depends on the direction of the track relative to the applied field.

RECOMBINATION, PREFERENTIAL. Recombination which takes place immediately after the **ion-pair** is formed, if the components are not separated quickly enough by the applied field or are deflected back toward one another by collisions with other molecules.

RECOMBINATION RATE, SURFACE. The time rate at which free electrons and **holes** recombine at the surface of a **semiconductor.**

RECOMBINATION RATE, VOLUME. The time rate at which free electrons and **holes** recombine within the volume of a **semiconductor.**

RECOMBINATION VELOCITY (ON A SEMICONDUCTOR SURFACE). The quotient of the normal component of the electron (**hole**) current density at the surface by the excess electron (hole) charge density at the surface.

RECOMBINATION, VOLUME. Recombination which takes place between positive and negative ions at low energies throughout the volume of an **ionization chamber** or **counter.**

RECONTROL TIME IN THYRATRONS. The **deionization time.**

RECORDING, CARBON. In **facsimile,** the recording of a received signal by a carbon paper-white paper combination which is struck or indented by an electromechanical **transducer.**

RECORDING CHANNEL. One of a number of independent recorders in a recording system or one of two or more independent recording tracks on a recording medium. One or more channels may be used at the same time for covering different ranges of the transmitted frequency band, for multichannel recording, or for control purposes.

RECORDING, CONSTANT AMPLITUDE. A mechanical recording characteristic wherein, for a fixed amplitude of a sinusoidal signal, the resulting recorded amplitude is independent of frequency.

RECORDING, CONSTANT VELOCITY. A mechanical recording characteristic wherein, for a fixed amplitude of a sinusoidal signal, the resulting recorded amplitude is inversely proportional to the frequency.

RECORDING, INSTANTANEOUS. A recording which is intended for direct reproduction without further processing.

RECORDING, LATERAL. A mechanical recording in which the groove modulation is perpendicular to the motion of the recording medium and parallel to the surface of the recording medium.

RECORDING SYSTEM, MULTITRACK. A recording system which provides two or more recording paths on a medium, which may carry either related or unrelated recordings in common time relationship

RECORDING SYSTEM, SOUND. A combination of transducing (see **transducer**) devices and associated equipment suitable for storing sound in a form capable of subsequent reproduction.

RECORDING, VERTICAL (HILL AND DALE RECORDING). A mechanical recording in which the groove modulation is in a direction perpendicular to the surface of the recording medium.

RECOVERY OF METALS. The return to its original dimensions of a metal body, such as a wire, after it has been stressed The complete recovery may require a definite period of time, called relaxation time. The concept of recovery is also associated with the return to the original damping coefficient of an oscillating spring following a large number of oscillations. (See **elastic after-effect; fatigue.**)

RECOVERY TIME (OF A RADIATION COUNTER). The minimum time from the start of a counted **pulse** to the instant a suc-

ceeding pulse can attain a specific percentage of the maximum value of the counted pulse.

RECRYSTALLIZATION. Metals and alloys consist of an aggregate of individual grains or crystals. When subjected to mechanical deformation, as in rolling, forging or wire-drawing, the grains are distorted, usually elongated, and if severely worked, as by a 50% reduction in thickness by cold-rolling, the grains will be fragmented. Recrystallization is the growth of certain of the grain fragments at the expense of others, resulting in larger, strain-free grains. The recrystallization process is possible because of the increased atomic activity at the elevated annealing temperature.

RECTANGULAR COORDINATES. **Cartesian coordinates** with three mutually perpendicular axes, used for locating the position of a point in space. A convention must be established for the relative arrangement of the three axes The usual case, which is called a right-handed system, may be described as follows. Calling the axes OX, OY, OZ, choose the XY-plane to lie in the plane of the paper with the positive OX-axis pointing to the reader's right and the positive OY-axis pointing toward the top of the page The positive OZ-axis is then pointing upward from the page toward the reader If a pair of axes is exchanged, the system becomes left-handed.

RECTANGULAR SCANNING. See **scanning, rectangular.**

RECTIFICATION FACTOR. The quotient of the change in average current of an electrode by the change in amplitude of the alternating sinusoidal voltage applied to the same electrode, the direct voltages of this and other electrodes being maintained constant.

RECTIFIER. A device having an asymmetrical conduction characteristic which is used for the conversion of an alternating current into a current having a unidirectional component.

RECTIFIER, BRIDGE. A full-wave **rectifier** with four rectifying elements or groups of elements connected as in a **bridge circuit.**

RECTIFIER, COMPLEMENTARY. Half-wave rectifying circuit elements connecting in series with output windings of a **saturable reactor** in the self-saturating **magnetic amplifier** circuit.

RECTIFIER, CONTACT. A **rectifier** consisting of two different solids in contact, in which rectification is due to greater conductivity across the contact in one direction than in the other.

RECTIFIER, COPPER-OXIDE. A **semiconductor rectifier** utilizing the **barrier layer** developed between metallic copper and cuprous oxide The units are low in efficiency, but noted for extremely long life.

RECTIFIER, COPPER SULFIDE. A **semiconductor rectifier** in which the rectifying **barrier** is the **junction** between magnesium and copper sulfide.

RECTIFIER, CRYSTAL. See **rectifier, contact; diode, crystal.**

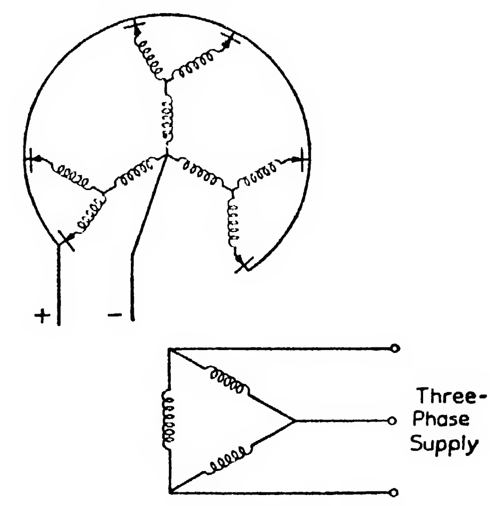
RECTIFIER, DEMODULATOR. See **demodulator rectifier.**

RECTIFIER, DOUBLE-Y. Two three-phase, half-wave, Y-connected **rectifiers** operating effectively in parallel with respect to the output, but with the relative phase voltages in the two systems 60° out of phase The result is a six-phase system with a high **utilization factor.**

RECTIFIER, DRY-DISK. A **semiconductor rectifier** with a disk-shaped barrier. (See **copper-oxide rectifier; selenium rectifier.**)

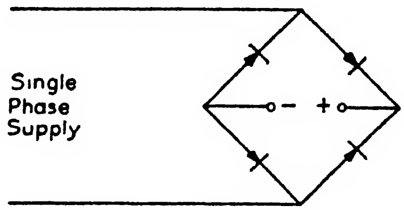
RECTIFIER, ELECTROLYTIC. See **electrolytic rectifier.**

RECTIFIER, FORK. A six-phase, half-wave rectifier as shown in the figure.



Fork rectifier

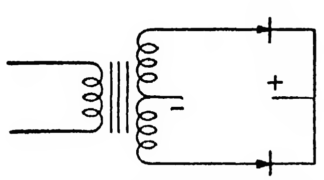
RECTIFIER, FULL-WAVE BRIDGE. A



Full-wave bridge rectifier

full-wave bridge rectifier as shown in the figure.

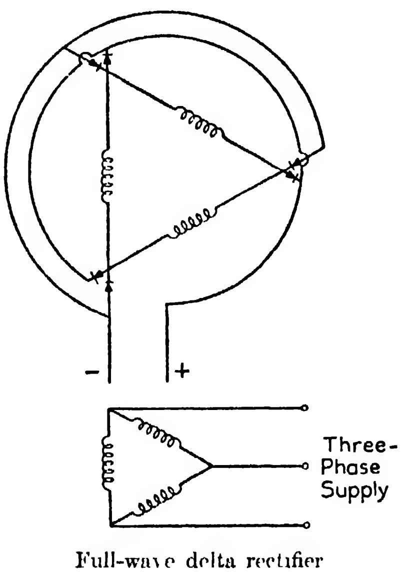
RECTIFIER, FULL-WAVE, CENTER-TAP.



Full-wave center-tap rectifier

A full-wave, center-tap rectifier as shown in the figure.

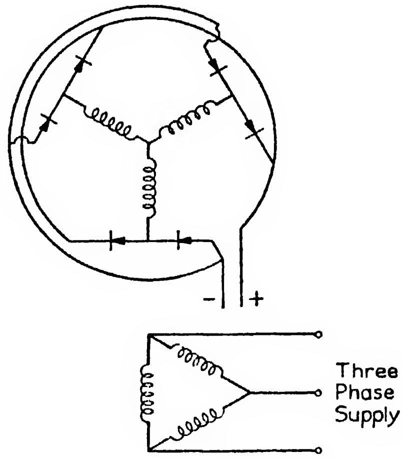
RECTIFIER, FULL-WAVE DELTA. A



Full-wave delta rectifier

three-phase, full-wave rectifier as shown in the figure.

RECTIFIER, FULL-WAVE WYE. A three-



Full-wave wye rectifier

phase, full-wave rectifier, as shown in the figure.

RECTIFIER, GRID-CONTROLLED, MERCURY-ARC. A mercury-arc **rectifier** in which one or more electrodes are employed exclusively to control the starting of the discharge, as in a **thyratron.**

RECTIFIER, HALF-WAVE. A **rectifier** which utilizes only half of the input-alternating waveform. (See **rectifier, zig-zag.**)

RECTIFIER, JUNCTION. A voltage applied to a ***p-n* junction** can carry a current easily if it tends to increase the number of **minority carriers** in each part, but not otherwise. The **forward direction** is thus that which carries **holes** into the ***n*-type** material. Practical devices, such as the selenium and copper-oxide rectifiers, depend on such a junction being formed at some point in the layer structure, e.g., between the oxygen-rich and copper-rich cuprous oxide layers formed on copper by direct oxidation.

RECTIFIER, LINEAR. A **rectifier,** the output current or voltage of which contains a wave having a form identical with that of the envelope of an impressed signal wave.

RECTIFIER, MAGNETRON. A cold-cathode, gas diode **rectifier** which is controlled with an external field.

RECTIFIER, MERCURY-ARC. See **mercury-arc rectifier; pool-cathode tube.**

RECTIFIER, METAL-TANK, MERCURY-ARC. A pool-type, mercury-arc **rectifier** enclosed in a metal tank which generally serves as a cathode terminal and heat radiator. (See **excitron** and **ignitron.**)

RECTIFIER, PHASE SHIFTING. See **phase control.**

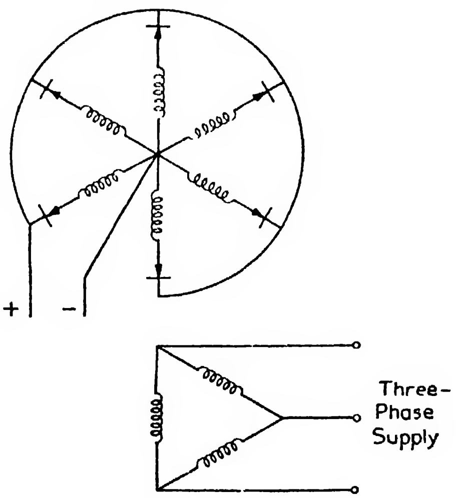
RECTIFIER, POINT CONTACT. A rectifying device depending on the ability of a metallic point applied to a **semiconducting** crystal surface to inject **holes** when biased positively with respect to the surface. This is the principle of the **crystal detector,** and is due to the binding of electrons in **surface states.**

RECTIFIER, POOL-CATHODE. See **pool-cathode tube.**

RECTIFIER, SELF-SATURATING. Half-wave rectifying circuit elements connecting in series with output windings of a **saturable reactor** in the self-saturating **magnetic amplifier** circuit.

RECTIFIER STACK. An assembly of **semiconductor** rectifier elements or cells.

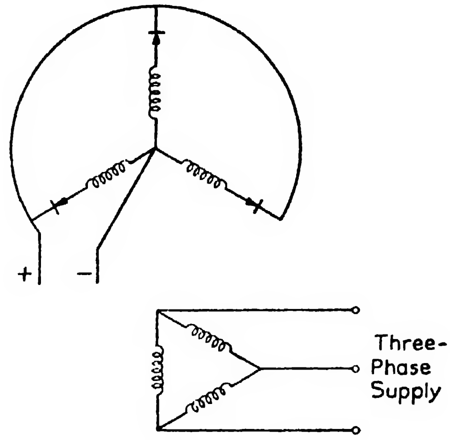
RECTIFIER, STAR. A six-phase, half-wave rectifier as shown in the figure.



Star rectifier

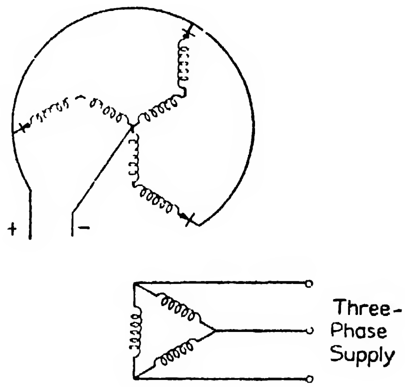
RECTIFIER VOLTMETER. See **voltmeter, rectifier.**

RECTIFIER, WYE. A three-phase, half-wave rectifier as shown in the figure.



Wye rectifier

RECTIFIER, ZIG-ZAG. A three-phase, half-wave rectifier as shown in the figure.



Zig-zag rectifier

RECTIGON. A relatively high-pressure thermionic-cathode **gas-diode** used primarily for battery charging. Rapidly being replaced by dry-disk semiconductor rectifiers.

RECTILINEAR DIAMETERS, LAW OF. See **Cailletet and Mathias, law of.**

RECTILINEAR MOTION OF A PARTICLE. The motion of a particle in a straight line. The motion takes place in accordance with the type of force acting on particle. Some common examples are listed below.

(1) No force. $x = v_0 t + x_0$
x_0 is the initial displacement
v_0 is the velocity (constant)

(2) Constant force.

$$x = \frac{1}{2}\left(\frac{F_0}{m}\right) t^2 + v_0 t + x_0$$

F_0 is force (constant in magnitude and direction)
m is mass of particle
v_0 is initial velocity
x_0 is initial displacement

(3) Force proportional to first power of distance from a fixed point

A. Attractive force. $F = -kx$

$$x = A \begin{matrix} \sin \\ \cos \end{matrix} \left\{ 2\pi \sqrt{\frac{k}{m}}\, t + \epsilon \right\}$$

Cf. simple harmonic motion

B. Repulsive force. $F = kx$

$$x = R \cosh \frac{k}{m} t \text{ (catenary)}$$

R is initial displacement from fixed point (initial velocity is zero)

(4) Attractive force. Force inversely proportional to square of distance from fixed point. $F = -\frac{k}{x^2}$

$$\sqrt{R_0 x - x^2} - R_0 \sin^{-1} \sqrt{\frac{x}{R_0}} + \frac{R_0 \pi}{2} = \sqrt{\frac{2k}{R_0 m}}\, t$$

R_0 is initial displacement from fixed point (initial velocity is zero)

RECTILINEAR SCANNING. See **scanning, rectilinear.**

RECTILINEAR SYSTEM. An optical system corrected for both **distortion** and **spherical aberration.** (Also called **orthoscopic.**)

RECURSION FORMULA. Relations between successive coefficients in a series, frequently the **series solution** of a differential equation, making it possible to calculate the $(n + 1)$th member of the series if the nth, $(n - 1)$th, etc., members are known. They usually involve only two coefficients but in some more complicated cases, the **Mathieu equation,** for example, they involve three coefficients.

RECYCLING DETECTOR. In the conventional detector (the **linear-diode detector,** for example) the capacitor across the detector output has an exponentially-decaying voltage between carrier cycles. In the recycling detector the capacitor voltage remains unchanged until just before the next carrier cycle, when it is intentionally reduced to zero by a switching circuit. The results are higher output and greater elimination of the carrier in the output.

RED-SHIFT. Displacement, toward the red end of the spectrum, of familiar absorption lines in spectra of the light of stars, nebulae, and luminous astronomical objects in general. (See **red shift (gravitational)**; and **red shift (nebulae).**)

RED SHIFT (GRAVITATIONAL). Consequence of general relativity theory (see **relativity theory, general**) that the periods of identical oscillators at different points depend on the gravitational potentials at those points. The wavelength of a spectral line coming from the sun should thus exceed that of the corresponding line from a source on the earth by the fraction 2.12×10^{-6}.

RED SHIFT (NEBULAE). Displacement towards the red of spectral lines from distant nebulae, usually interpreted as a **Doppler effect** due to their motion away from our galaxy. (See **Hubble constant; expanding universe.**)

REDUCED EQUATION OF STATE. A generalized **equation of state** containing as variables the reduced pressure, reduced volume, and reduced temperature. In the case of **van der Waals' equation,** the form is:

$$\left(\pi + \frac{3}{\phi^2}\right)(3\phi - 1) = 8\theta$$

where π is the reduced pressure, defined as the ratio of the existing pressure to the **critical pressure;** ϕ is the reduced volume, defined as the ratio of the existing volume to the **critical volume;** and θ is the reduced temperature, defined as the ratio of the existing temperature to the **critical temperature.**

REDUCED FOCAL LENGTH. The first **focal length** of a spherical-refracting surface, or of a lens, divided by the **refractive index** of the medium in which the light is incident; or the second focal length divided by the refractive index of the medium into which the rays emerge.

REDUCED MASS. In treating any two body problem, the most satisfactory coordinate frame in which the laws of motion may be applied is an inertial system, i.e., a system which is not accelerated with respect to the fixed stars. The center of mass system of two bodies, having masses M and m and acted on only by mutual forces, is such an inertial system. When the equations of motion are transformed to center of mass coordinates, it is found that they are identical with equations in a system having its origin fixed at M if the mass m is replaced by the reduced mass $\mu = Mm/(M + m)$. If $M \gg m$, the reduced mass is closely approximated by m.

REDUCED MASS OF DIATOMIC MOLECULE. For a diatomic molecule regarded as a rigid rotator (dumbbell model) the reduced mass μ is

$$\mu = \frac{m_1 m_2}{m_1 + m_2}$$

where m_1, m_2 are the masses of the two atoms.

REDUCTION FORMULA. Used in evaluating an **integral** when the **integrand** is of the form $x^m(a + bx^n)^p$. Introduction of a new variable and integration by parts converts the integral successively into simpler integrals. One example is

$$\int x^m(a + bx^n)^p dx = \frac{x^{m-n+1}(a + bx^n)^{p+1}}{(np + m + 1)b}$$

$$- \frac{(m - n + 1)a}{(np + m + 1)b} \int x^{m-n}(a + bx^n)^p dx$$

where p is a rational number, n is positive, and m, n are integers. Although the original integral may have been difficult to solve, the reduced form on the right may be easier. If not, apply the formula again. Several alternative relations may be derived, for the exponents m, p may be either increased or decreased.

REDUCTION OF AREA. See **Poisson ratio.**

REDUCTION POTENTIAL. The potential drop involved in the reduction of a cation to a neutral form, as in the **electrolytic deposition** of metals; or the reduction to a less highly-charged ion, as in the reduction of ferric to ferrous ions.

REDUNDANCY. The fraction of the specification of a message which is unnecessary. It is equal to one minus the relative **entropy (2).**

REFERENCE BLACK LEVEL. The picture signal level corresponding to a specified maximum limit for black peaks.

REFERENCE DEFLECTION. The deflection to the meter-scale point marked 0 **vu**, 100 **vu**, or both. This is the deflection at which the meter should be used.

REFERENCE VOLUME. The level which gives a reading of 0 **vu** on a standard volume indicator. The "reading of 0 vu" is the algebraic sum of the meter and attenuator readings on the **standard volume indicator.**

REFERENCE WHITE LEVEL OF A COMPOSITE PICTURE SIGNAL. A level removed (in the direction of white) from the **synchronizing signal peak** by an amount equal to 4.0 times the **peak-to-peak amplitude** of the synchronizing signal component.

REFLECTANCE. When used without qualification the term reflectance usually refers to radiant reflectance. (See **reflectance, radiant.**)

REFLECTANCE, LUMINOUS. The ratio of the luminous emittance (see **emittance, luminous**) to the **illuminance** of a reflecting surface, both quantities being expressed in consistent units.

REFLECTANCE, RADIANT. The ratio of the reflected radiant flux (see **flux, radiant**) to the incident radiant flux.

REFLECTANCE, SPECTRAL. The radiant reflectance (see **reflectance, radiant**) for a specified wavelength of the incident radiant flux.

REFLECTANCE, SPECULAR. The ratio of (1) the **radiance** measured by reflection to (2) the radiance measured directly. This quantity (specular reflectance) is a function of the angle of incidence (and reflection), and of the spectral composition of the incident energy (unless the mirror is nonselective).

REFLECTED WAVE. See **wave, reflected.**

REFLECTING FILMS, HIGH-EFFICIENCY. See **high-efficiency reflecting films.**

REFLECTING GRATING. See **radial grating, waveguide filter.**

REFLECTING TELESCOPE. A **telescope** in which the principal light-gathering optic is a concave mirror. [1955] The largest refracting telescope is the 40-inch Yerkes telescope, the larger 200-inch on Mt. Palomar is a reflecting telescope.

REFLECTION. When an emission, such as radiation or sound, traveling in one medium encounters a different medium, part of it in general passes on and undergoes **refraction,** while part is reflected. Even water waves exhibit reflection upon meeting an obstacle, and some of the characteristics of the process are conveniently observed by watching surface ripples. In all cases of "regular" reflection, in which the direction of propagation is sharply defined after reflection, the change takes place in accordance with a very simple law, viz., the reflected and incident wave trains travel in directions making equal angles with the normal to the reflecting surface and lie in the same plane with it. These angles are called, respectively, the angle of reflection and the angle of incidence. For normal incidence, both of these angles are zero. Rough surfaces reflect in a multitude of directions, and such reflection is said to be "diffuse." Only part of the emission or of the energy associated with it is reflected; the ratio of that part to the whole incident emission is called the "reflectivity" of the surface.

REFLECTION, ABNORMAL. See **abnormal reflection.**

REFLECTION BY METALS. See **refractive index for metals.**

REFLECTION COEFFICIENT. For plane waves or transmission lines, the ratio of the reflected wave to the incident wave. By extension, the concept is applied to **networks** to express the effect of an **impedance mismatch.** From the general conception, three specific definitions follow: (1) The acoustic reflection coefficient is the ratio of the flow of reflected sound energy to the flow of incident sound energy. (2) For a **transition** or **discontinuity** between two transmission media, the reflection coefficient is that which would be observed at a specified point in one medium if the other medium were **match-terminated.** (3) The reflection coefficient in a transmission medium is defined as follows: At a given point, and for a given mode of transmission, the ratio of some quantity associated with the reflected wave to the corresponding quantity in the incident wave. The reflection coefficient may be different for different associated quantities, and the chosen quantity should be specified. The "voltage reflection coefficient" is most commonly used, and is defined as the ratio of the complex **electric field strength** (or voltage) of the reflected wave to that of the incident wave.

REFLECTION FACTOR. The same as **reflection coefficient,** also sometimes called mismatch factor or transition factor.

REFLECTION GRATING. A **grating** ruled on a reflecting surface such as speculum metal or a glass-chromium-aluminum surface. (See Robertson, *Introduction to Optics,* 4th Ed., p. 235 ff.)

REFLECTION GRATING, CONCAVE. A **grating** ruled on the surface of a concave mirror. The use of concave reflection gratings may avoid the presence of lenses in the system, with their absorption losses.

REFLECTION GRATING, ROWLAND ARRANGEMENT. A mounting for a concave **reflection grating** in which the **slit,** the grating and the photographic plate all lie on the

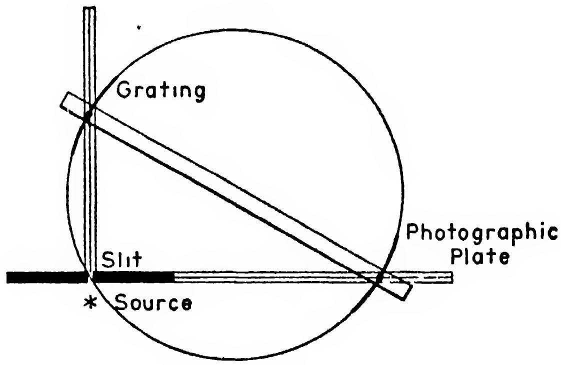


Fig. 1

circumference of a circle. One system, shown in Fig. 1, is to have the three independently mounted on a circular track. A more com-

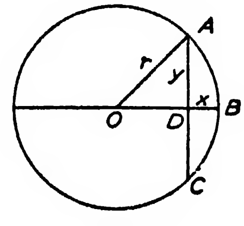


Fig. 2

mon system is as indicated in Fig. 2. The grating and photographic plate are mounted on the ends of a rod of fixed length. The ends of this rod ride on two, mutually-perpendicular tracks. The slit is at the intersection of the tracks.

REFLECTION LOSS. (1) That part of the **transition loss** due to the reflection of power at a discontinuity. (2) The ratio in **decibels** of the power incident upon a discontinuity to the difference between the power incident upon and the power reflected from the discontinuity.

REFLECTION, MULTIPLE. See **multiple reflection.**

REFLECTION PLANE. A **symmetry element** possessed by certain crystals, whereby one-half of the crystal is the reflection of the other half in a plane drawn through the center of the crystal.

REFLECTION, TOTAL. See **total reflection.**

REFLECTIVITY. The fraction of the incident **radiant energy** reflected by a surface that is exposed to uniform radiation from a source that fills its field of view.

REFLECTOMETER. (1) In optics, an instrument for measuring the **reflectance** of reflecting surfaces. (2) In electronics, a directional coupler containing matched calibrated detectors in both arms of the auxiliary line, or a pair of single-detector couplers oriented so as to measure the power flowing in both directions in the main line.

REFLECTOR. (1) A scattering substance surrounding the core of a nuclear **reactor,** used for the purpose of reducing the loss of neutrons due to leakage, and therefore, making the dimensions of the reactor smaller. Common reflectors are water, graphite, beryllium, etc. (2) In antenna terminology, a **parasitic element** located in a direction other than the general direction of the major **lobe** of radiation. An example is an antenna wire placed behind a **dipole** to improve its directional characteristics and **gain.**

REFLECTOR, COMPENSATED. A corner reflector (see **reflector, corner**) modified to provide an increase in the range of angles over which it may be operated.

REFLECTOR, CORNER. (1) A reflector (see **reflector (2)**) consisting of two or three mutually-intersecting, conducting surfaces. Corner reflectors may be dihedral or trihedral. Trihedral reflectors may be used as radar targets. (2) A reflector (see **reflector (2)**) which consists of two plane-conducting surfaces set at an angle of 45° to 90° with the driven element on a line bisecting the angle. The reflecting surfaces are not necessarily solid, but can be made from wires spaced about 0.1 wavelength apart. In a given amount of space, the corner reflector gives better directivity than the parabolic reflector.

REFLECTOR, CUT PARABOLOIDAL. A paraboloidal reflector (see **reflector, paraboloidal**) which is not symmetrical with respect to its axis.

REFLECTOR, CYLINDRICAL. A **reflector** which is a portion of a cylinder. This cylinder is usually parabolic, although other shapes may be used.

REFLECTOR, GRATING. In antenna terminology, an open-work metal structure designed to provide a good reflecting surface.

REFLECTOR, PARABOLIC. A **reflector** consisting of some form of a paraboloidal mirror. Usually used in conjunction with an antenna.

REFLECTOR, PARABOLOIDAL. A **reflector** which is a portion of a paraboloid of revolution.

REFLECTOR SAVINGS. See **reactor, reflector savings of.**

REFLEX BAFFLE. A loudspeaker baffle in which a portion of the radiation from the rear of the diaphragm is propagated forward after controlled shift of phase or other modification, the purpose being to increase the over-all radiation in some portion of the frequency spectrum.

REFLEX CIRCUIT (AMPLIFIER). A circuit in which one tube simultaneously amplifies signals in two widely-separate **frequency bands** (i.e., the intermediate frequency signal of a superheterodyne and the audio frequency output of the detector). Now little used because the savings of material and space are not justified by the additional complexity of operation.

REFRACTED WAVE. See **wave, refracted.**

REFRACTING TELESCOPE. A **telescope** in which the principal light-gathering optic is a **lens.**

REFRACTION. (1) The bending of a ray of light or other radiation as it passes from one medium to another of different **refractive index** (see the **Snell laws**) (2) The variation of the direction of sound transmission due to spatial variation of the wave velocity in the medium.

REFRACTION, ATOMIC. The product of the specific refraction (see **refraction, specific**) of an element by its **atomic weight.**

REFRACTION, CONICAL. See **conical refraction.**

REFRACTION, DESCARTES LAWS OF. See **Descartes laws of refraction.**

REFRACTION, DOUBLE. See **double refraction.**

REFRACTION LOSS (SOUND). That part of the **transmission loss** due to refraction resulting from nonuniformity of the medium.

REFRACTION, MOLAR. The product of the specific refraction (see **refraction, specific**) by the **molecular weight.** The form of this relationship is

$$[R] = Mr$$

in which $[R]$ is the molar refraction, M is the molecular weight, and r is the specific refraction The direct form of this relationship is

$$[R] = \left(\frac{n^2 - 1}{n^2 + 2}\right)\left(\frac{M}{\rho}\right)$$

in which $[R]$ is the molar refraction, n is the index of refraction for any chosen wavelength, M is the molecular weight, and ρ is the density.

REFRACTION OF SOUND, CONVECTIVE. The refraction of sound in a single medium, such as the atmosphere, by the effect of wind on the sound velocity

REFRACTION OF SOUND, TEMPERATURE. The refraction of sound in a single medium, such as the atmosphere, by the effect of point-to-point temperature variations.

REFRACTION, SPECIFIC. A relationship between the refractive index of a medium at any definite wavelength and its density, of the form

$$r = \left(\frac{n^2 - 1}{n^2 + 2}\right)\left(\frac{1}{\rho}\right)$$

in which r is the specific refraction of the medium, n is its index of refraction at any definite wavelength, and ρ is its density. The relation does not always give a constant value of r as the density is varied, and hence must be considered as an approximation

REFRACTION, STANDARD. The **refraction** which would occur in an idealized atmosphere in which the **index of refraction** decreases uniformly with height at the rate of 39×10^{-6} per kilometer. Standard refraction may be included in ground wave calculations by use of an effective earth radius of 8.5×10^6 meters, or 4/3 the geometrical radius of the earth.

REFRACTIVE. Having or exhibiting the property of **refraction.**

REFRACTIVE DISPERSIVITY. The derivative of the **refractive index** with respect to wavelength or frequency.

REFRACTIVE INDEX. The **phase velocity** of radiation in free space divided by the **phase velocity** of the same radiation in a specified medium. Because of the Snell law, refractive index may also be defined as the ratio of the sine of the **angle of incidence** (*in vacuo*) to the sine of the **angle of refraction.** Because the refractive index of air is only about 1.00029, refractive index is frequently measured with respect to air rather than with respect to free space (vacuum). Excepting a few very special cases (x-rays' light in metal films) the refractive index is a number greater than unity. A few representative values are $n_{\text{water}} = 1.34$, $n_{\text{glass}} = 1.5$–1.9, $n_{\text{germanium}} = 4.25$ (infrared radiation).

REFRACTIVE INDEX, COMPLEX. See **complex refractive index.**

REFRACTIVE INDEX FOR METALS. For metals which absorb strongly, the customary **refractive index** must be replaced by the complex refractive index $n(1 - i\kappa)$ where κ is the

absorption index. Then the **reflectivity** for normal incidence is

$$R = \frac{(n-1)^2 + n^2\kappa^2}{(n+1)^2 - n^2\kappa^2}.$$

The refractive index for metals varies over a much larger range for metals than for conventional dielectrics, e.g., sodium at $\lambda = 0.546$ micron, $n = 0.052$ while silicon at $\lambda = 0.589$ micron, $n = 4.24$.

REFRACTIVE INDEX, MAXWELL RELATIONSHIP FOR. The **dielectric constant** of a nonpolar substance which has no permanent molecular **dipole moment** is equal to the square of its refractive index, when the latter is measured for a light radiation of long wavelength.

REFRACTIVE INDEX, RELATIVE. Of two media, the ratio of their **refractive indices.**

REFRACTIVE MODULUS. In the **troposphere,** the excess over unity of the modified **refractive index** expressed in millionths. It is represented by M and is given by the equation

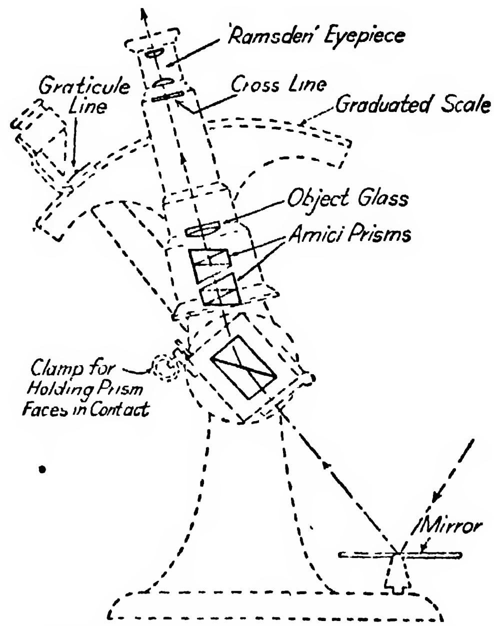
$$M = (n + h/a - 1)10^6$$

where n is the index of refraction at a height h above sea level, and a is the radius of the earth.

REFRACTIVITY. (1) In general, the property of **refraction,** or a quantitative relationship by which it is expressed, which is commonly some function of the index of refraction. (2) The quantity $(n - 1)$ which enters many optical formulas is sometimes called "refractivity." Here n is the **refractive index.**

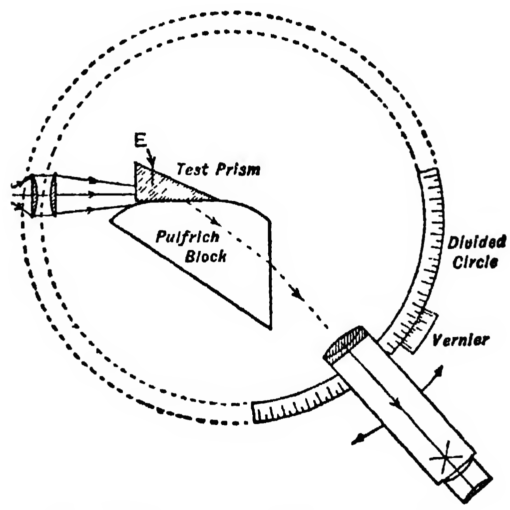
REFRACTOMETER. An instrument for measuring the **refractive index** of a substance. Several types of such instruments have been developed, including special forms used for solids, for liquids and for gases.

REFRACTOMETER, ABBE. A type of **refractometer** used for liquids. A film of the liquid is clamped between two similar glass prisms (see figure), and the total reflection at the interface observed. Any spectrometer, with a pair of good prisms (preferably right-angled) mounted on the prism table, can be used in this way.



Optical system of Abbe refractometer

REFRACTOMETER, PULFRICH. Suppose that a specimen of the solid or liquid to be tested is brought into optical contact with one face of a glass prism (or "block") of known,

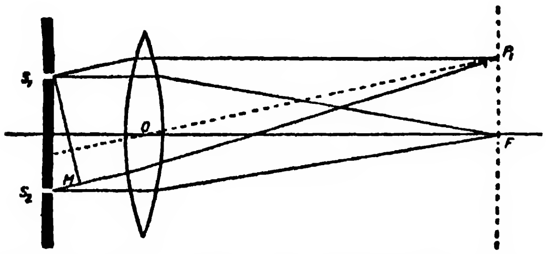


Pulfrich refractometer (diagrammatic)

higher refractive index and known angle, and that a slightly convergent pencil of light, entering the test substance, is directed at grazing incidence upon the interface between it and the prism. Those rays incident at less

than 90° to the normal of the interface enter the prism; the others do not, and the boundary between is sharply defined. The resulting half-pencil traverses the prism and emerges from the other face where the direction of its cut-off edge can be observed (see figure). The angle between the cut-off boundary of the pencil and the first prism face, inside the prism, is the critical angle, and can be easily calculated from the observations and the known data.

REFRACTOMETER, RAYLEIGH. An instrument in which light from a slit is divided, passed along two parallel paths, and then reunited. The introduction of anything into



When a double slit S_1S_2, illuminated by light from a distant narrow source, is placed in front of the objective of a telescope, interference fringes are observed in the focal plane P_1F (By permission from "Introduction to Optics, Geometrical and Physical" by Robertson, 4th Ed., Copyright 1954, D. Van Nostrand Co., Inc.)

one path which slightly changes the speed of the light will result in **interference** between the two beams when they are reunited.

REFRACTOMETER, WILLIAMS. A **refractometer** in which light from a single slit is divided by a five-sided prism into two beams. It has a **resolving power** considerably greater than the customary two-slit refractometer.

REFRANGIBLE. Capable of being refracted, or measurably deviated by **refraction.**

REFRIGERANT. A substance which is suitable as the working medium of a cycle of operations wherein refrigeration is accomplished.

REFRIGERATION CYCLE. A cycle that takes heat at a lower temperature and rejects it at a higher. Such a cycle must receive a power input from an external source, and the amount of heat rejected exceeds that taken in by the amount of work required to effect the cycle. Theoretically, any power cycle which is reversible could be reversed to create a refrigeration cycle. Actually, practical considerations have caused modification of the reversed power cycle for refrigeration use. Nevertheless, the ordinary vapor compression refrigerating cycle resembles the **Rankine** power cycle to a close degree.

REGELATION. This thermal phenomenon is a direct consequence of the fact that the melting point of ice is measurably lowered by intense pressure. Ice at the normal melting point will, if it is subjected to pressure, become liquid, and will "regelate" or refreeze when the pressure is removed. Crushed ice or snow may thus be molded into clear blocks of any desired shape. A small, heavy object placed on a cake of ice not too far below the melting point will gradually bury itself in the ice, the water which results from the pressure escaping from under it and refreezing above it. In the same way a cake of ice resting on a metal grid will hook itself around the bars of the grid. Ice is slippery even when below the freezing point, because the pressure of any hard object, as a skate blade, produces a film of water at the surface of contact. Water extruded under pressure from the terminal wall of ice at the foot of a **glacier** sometimes freezes into snakelike spirals of ice. Regelation is believed to explain the flowing motion of the glacier itself. Only substances which, like water, expand on freezing are capable of exhibiting regelation.

REGENERATION. See **feedback, positive.**

REGENERATION, DOUBLE. Regeneration supplied to two or more stages simultaneously.

REGENERATIVE DETECTOR. See **detector, balanced.**

REGENERATIVE OSCILLATOR. See **oscillator, feedback.**

REGENERATIVE REPEATERING. A process in which each code element in a message is replaced by a new code element of specified timing, waveform, and magnitude.

REGION OF LIMITED PROPORTIONALITY. The range of applied voltage below the **Geiger-Mueller threshold,** in which the **gas**

amplification depends upon the charge liberated by the initial **ionizing event.**

REGISTER. A device capable of retaining information which is usually a **subset** of the aggregate information in a **digital computer.**

REGNAULT METHOD FOR VAPOR PRESSURE. See **direct or static methods for vapor pressure (2).**

REGULA FALSI, METHOD OF. A procedure for solving **transcendental** or other numerical equations. Suppose the given equation is $f(x) = 0$ and that $y = f(x)$ is a plot of the function for various values of x. Further suppose that x_0, x_1 and y_0, y_1 are two sets of numbers obtained from such a graph. Then a more exact value of the **root** is

$$x = x_0 + \Delta x,$$

where $\Delta x = \dfrac{(x_1 - x_0)|y_0|}{|y_0| + |y_1|}$.

REGULAR. See **analytic.**

REGULARIZATION. Formal device introduced into quantized field theory (see **field theory, quantized**) in order to remove ambiguities arising in the evaluation of certain integrals. Corresponds to adding extra fields with different masses which then are allowed to tend to infinity.

REGULATION (OF A GLOW-DISCHARGE COLD-CATHODE TUBE). The difference between the maximum and minimum anode voltage-drop over a range of anode current.

REGULATION, VOLTAGE. The voltage regulation of a circuit or device is:

$$100 \times \frac{(\text{No load voltage}) - (\text{full load voltage})}{(\text{full load voltage})}.$$

REGULATOR TUBE. One of the characteristics of the glow and arc types of **discharge** is their tendency to maintain a constant voltage across the tube. This property is used in the various voltage regulator tubes, which are two **electrode** glow discharge tubes operated in the current range where this constant voltage characteristic is very pronounced. When such a tube is connected in series with a **resistance** across a source of d-c it will maintain a constant voltage across its terminals for wide variations in the source voltage. While the current which can be supplied by such a circuit is rather limited, it is sufficient for numerous electronic circuits.

REGULEX. Trade name for a form of dynamoelectric amplifier. (See **amplifier, dynamoelectric.**)

REIGNITION, COUNTER TUBE. See **counter tube reignition.**

REIGNITION VOLTAGE. In a **gas-discharge** device, that voltage which, if applied during the **deionization period,** is just sufficient to reestablish conduction. It is an inverse function of time, being essentially equal to the normal discharge-drop when the discharge has just been extinguished, and approaching the peak forward voltage as the deionization process is completed.

REINSERTER. See **restorer, d-c.**

REINSERTION, D-C. In television, the readjusting of the **video signal** at the image tube to the form it possessed when transmitted by the broadcast station. Passage of the video signal through the a-c coupling networks of the video amplifiers results in the removal of the d-c component of the signal. A d-c **restorer circuit,** just prior to the cathode-ray tube, reinserts this lost d-c component.

REJECTION BAND. A band of frequencies in which the signals are selectivity attenuated or eliminated. In a uniconductor waveguide, the frequency range below the cut-off frequency.

REJECTOR CIRCUIT. A band-rejection filter. (See **filter, band-rejection.**)

RELATIVE APERTURE (ACCELERATORS). (A) Vertical. The ratio of the minimum vertical clearance for particle passage (in the **accelerating chamber**) to the particle-orbit radius. (B) Horizontal. The ratio of the minimum horizontal clearance for particle passage (in the accelerating chamber) to the particle-orbit radius.

RELATIVE HUMIDITY. See **humidity, relative.**

RELATIVE LUMINOSITY. The ratio of the value of the **luminosity** at a particular wavelength to the value at the wavelength of maximum luminosity.

RELATIVE REFRACTIVE INDEX. See **refractive index, relative.**

RELATIVE RESPONSE. See **response, relative.**

RELATIVE VELOCITY. See **velocity, relative.**

RELATIVISTIC LIMIT, EXTREME. See **extreme relativistic limit.**

RELATIVISTIC MASS EQUATION. The equation

$$m = m_0(1 - v^2/c^2)^{-1/2},$$

where m is the relativistic mass of a body or particle of rest mass m_0, when its velocity relative to the observer is v, and c is the velocity of light.

RELATIVISTIC PARTICLE. A particle with a velocity so large that its **relativistic mass** exceeds its **rest mass** by an amount which is significant for the computation or other considerations at hand. (See **relativistic mass equation; relativistic velocity.**)

RELATIVISTIC QUANTUM MECHANICS. See **quantum mechanics (relativistic).**

RELATIVISTIC VELOCITY. A velocity sufficiently large that the values of some properties of a particle having this velocity are significantly different from the values of the same properties when the particle is at rest. The property of most interest is the mass. For many purposes, the velocity is relativistic when it exceeds about one-tenth the velocity of light. (See **relativistic particle; relativistic mass equation.**)

RELATIVITY. A principle that postulates the equivalence of the description of the universe, in terms of physical laws, by various observers, or for various frames of reference. A theory that utilizes such a principle is called a relativity theory. (See **relativity theory, general; relativity theory, special; relativistic mass equation; principle of mass-energy equivalence;** etc.)

RELATIVITY THEORY, GENERAL. Generalization of special relativity theory (see **relativity theory, special**) to relate the measurements of observers who are accelerated relative to each other and hence no longer in an inertial system. The fundamental postulate is the **principle of equivalence** from which may be deduced the equality of the **inertial mass** and **gravitational mass** of a system. In addition, one postulates a generalized relativity principle, that the equations of mechanics have the same form for all observers, whether accelerated or not. The essential equivalence between an externally applied "real" gravitational field and the "fictitious" inertial forces experienced by an accelerated observer is introduced by representing the motion of a system in **Riemannian space** of which the **metric** $g_{\mu\nu}$ represents the gravitational potentials, whether these be "real" or "fictitious." A test particle is then supposed to move along a **geodesic** in this space. The values of the $g_{\mu\nu}$ corresponding to a particular distribution of matter are given by the solution of the **Einstein law of gravitation.** For a point mass, the **Schwarzschild solution** of these equations leads directly to verified predictions of the **bending of light** in a gravitational field and the precession of the **perihelion of Mercury.** (Although electromagnetic phenomena have not been incorporated into general relativity theory in a completely satisfactory manner, the motion of a light ray is computed on the assumption that it moves along a **null-geodesic**, the natural generalization of the **null-cone** of **Minkowski space.**) In addition, the theory describes the gravitational **red shift** of light moving from one point to another in a gravitational field.

The three above-mentioned observational verifications of the theory are also described by theories developed in Minkowski space (see **Whitehead theory of gravitation**) but the satisfactory physical principle upon which general relativity theory is based makes it the most widely accepted theory of gravitation.

RELATIVITY THEORY, SPECIAL. Theory developed by Einstein based on the hypothesis that the velocity of light is the same as measured by any one of a set of observers moving with constant relative velocity. According to Newtonian theory and the **Galilean transformation** the mechanical motion of an object with respect to an inertial system could be predicted from a knowledge of the forces acting on it and the initial conditions, independently of any knowledge of the motion of the inertial system itself. Einstein extended this to optical phenomena, postulating that these also could be described without knowing the velocity of the laboratory with

respect to the rest of the universe. The null result of the **Michelson-Morley experiment** and of other attempts to measure the velocity of the laboratory relative to the ether (see **ether hypothesis**) was then interpreted as an immediate consequence of a fundamental principle of relativity, that the equations of electrodynamics have the same form in all systems in which the equations of mechanics are valid. From this principle, and the constancy of the velocity of light, it is possible to deduce the **Lorentz transformation** (appropriately modified in its interpretation so as to ignore the ether and to relate the observations of two observers moving with constant relative velocity). Since the **Maxwell equations** are covariant under this transformation but the equations of Newtonian mechanics are not, one is led to a modified description of the mechanics of particles which is in accord with the relativity principle. This description is indistinguishable from the Newtonian theory for systems in which all relative velocities are small compared with that of light, except that in this limit it also predicts that when a mass m_0 is annihilated an amount of energy $E = m_0c^2$ is released. In the more general case the mass of a particle is given by $m = \gamma m_0$ where m_0 is its **rest-mass** and $\gamma = (1 - \beta^2)^{-1/2}$, with $\beta = v/c$, v being the velocity of the particle relative to the observer, and the expansion of $E = mc^2$ in powers of β then yields $E = m_0c^2 + \frac{1}{2}m_0v^2 + \cdots$ the second term being the kinetic energy of the particle in Newtonian mechanics. The momentum of a particle then appears as mv, and the rate of change of this expression with respect to the time is equal to the force acting on the particle. The relation between the energy E and momentum p of a free particle then becomes $E^2 = p^2c^2 + m_0^2c^4$.

In addition to leading to such well-verified conclusions, special relativity theory was able to yield also the few valid consequences of the **ether hypothesis.** It provided the first verification of the **Mach principle** by its insistence on the rôle of the observer in the description of phenomena which the observer measures (cf. **quantum mechanics**) and pointed out that even the simultaneity of two **events** at different positions is not an intrinsic property of those events, but depends also on the motion of the observer who is recording them. This result emerges from Einstein's re-interpretation of the Lorentz transformation, referred to above, and is related to the consequent re-interpretation of the **Fitzgerald factor** and to the relativistic **slowing of clocks.**

The formal identification of a Lorentz transformation with a rotation in **Minkowski space** provides a basis for representing the equations of relativistic mechanics as relations between **four-vectors** analogous to representation of the non-relativistic equations as relations between vectors. In the same way that the latter representation ensures that the form of the equations shall be independent of the particular directions in which the chosen set of orthogonal axes happens to point, so the Minkowski representation ensures that the equations of relativistic mechanics shall be independent of which Lorentz observer is involved. All observers moving with constant relative velocity thus use equations of the same form to describe the optical and mechanical phenomena which they measure.

The theory has been generalized to include relatively accelerated observers (see **relativity theory, general**) and to include quantum phenomena (see **quantum mechanics (relativistic)**).

RELAXATION (PHENOMENA). Any phenomenon in which a system requires an observable length of time in order to respond to sudden changes in conditions, forces, or effects which are applied to the system

RELAXATION BEHAVIOR. All phenomena where consideration of equilibrium conditions alone would give an incomplete picture and where the study of the time-dependence of the approach to equilibrium is essential for an adequate comprehension of the effect.

RELAXATION FREQUENCY. In general terms, the inverse of the **relaxation time.** A system is usually incapable of reacting to any periodic stimulus whose frequency is very much higher than the relaxation frequency for the effect concerned.

RELAXATION INVERTER. A relaxation oscillator (see **oscillator, relaxation**), frequently employing gas-tubes, used to convert d-c power to a-c.

RELAXATION LENGTH. In nuclear **reactor** usage, the distance in which the intensity of a beam of **neutrons** or γ-rays (in a given medium) is reduced to a fraction $1/e$ of its

initial value due to absorption in the medium.

RELAXATION METHOD. Originally used in certain engineering problems in order to calculate displacements in a structure subjected to known loads, it may also be used to obtain **eigenvalues** and **eigenvectors** of algebraic or differential equations. Initial values of the eigenvalues and eigenvectors are put into the simultaneous equations of the problem. If they were the correct ones, each equation of the system would vanish; otherwise, there would be a set of residuals. The initial solutions are then varied (relaxed) until the residuals are minimized.

RELAXATION OSCILLATOR. See **oscillator, relaxation.**

RELAXATION TIME. In many material phenomena, the response to an abrupt change is often a time-measurable approach to equilibrium, frequently exponential. Examples are: (1) An abrupt change of **magnetizing force** usually does not produce an instantaneous, corresponding change in magnetic induction, but the new value is approached over a period of time. The time constant involved in such a phenomenon is often called relaxation time; if equilibrium is approached exponentially it is the time for $(1 - 1/e)$ of the total change to take place. (2) A case closely related to the foregoing is that of a crystal in which all the spins are aligned by a magnetic field, which is then removed. The magnetic moment will then decay to zero; if this decay is exponential with time, of the form $e^{-t/\tau}$, then τ is the relaxation time. (3) The time for which an electron may travel in a metal before it is scattered, and loses its momentum. (4) The time necessary for a stress in a Maxwellian fluid (see **fluid, Maxwellian**) at rest to decay to $1/e = 0.368$ of its initial value. The apparent solidification of vitreous materials is due to a very rapid increase in the relaxation time

RELAY. The electrical relay is a device which utilizes the variation of **current** in an **electric circuit** as a controlling factor in another. For example, a certain change of current in one circuit may cause current in another, by the operation of a relay connected between them. There are numerous types of electrical relays, as they have been widely used in industry, particularly in apparatus of an automatic or semi-automatic nature, or for the protection of electric power equipment, or for communication systems. Protective relays are highly specialized and developed to where they will detect any electrical abnormality, and open the circuit containing that abnormality in any required time interval. Suitable relays will detect over-current, under-current, over-voltage, under-voltage, overload, reverse current, reverse power, abnormal frequency, high temperature, grounds, and phase unbalance.

Usually the relay involves two circuits, the energizing circuit and the relay circuit (the latter variously called the trip circuit, the sounder circuit, etc.). Protective relays may close the trip circuit immediately, or after a definite time interval, or after an inverse time interval. If the trip circuit contacts are normally open, the relay is called circuit closing; if they are normally closed, the relay is called circuit opening.

RELAY, ALLSTRÖM. See **Allström relay.**

RELUCTANCE. See **magnetic circuit.**

RELUCTANCE PICKUP. A mechanical-electrical **transducer** in which the movement of an armature changes the **reluctance** of a magnetic path containing a permanent magnet, thus causing a change in flux which results in an induced voltage in the output coil(s).

REM. Abbreviation for **roentgen equivalent, man.**

REMANENCE. The **residual induction** B_r when the **magnetizing field** is reduced to zero from a value sufficient to saturate the material. (See **hysteresis.**)

REMOTE CONTROL. A system or method of controlling any equipment or assembly, such as a radio transmitter, whereby the control functions are performed from a distance, electrically, over intervening wire- or radio-circuits.

REMOTE CUT-OFF TUBE. A tube which, by virtue of unevenly-spaced grid-wires, has a **transconductance** which varies essentially logarithmically over an appreciable range of negative-grid voltages. The action is similar to that of several elemental tubes of different **amplification factors** operating in parallel. (See **tube, variable mu.**)

REMTRON. A **gas tube** frequently employed in **computers** and **counters.**

RENORMALIZATION OF CHARGE. See **self-charge.**

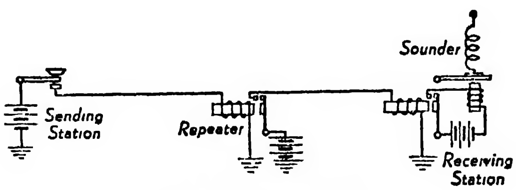
RENORMALIZATION OF MASS. Process of adding to the **mechanical mass** of a particle the extra mass it possesses in virtue of its self-interaction, and of recognizing that the measured mass is the sum of these two, which are not separately distinguishable experimentally. The process is of particular use in quantized field theory (see **field theory, quantized**), in which the mass arising from self-interaction is infinite.

REP. Abbreviation for **roentgen equivalent, physical.**

REPEAT POINT. The location on the tuning dial of a **superheterodyne receiver** which receives an **image-frequency** transmission.

REPEATABILITY. A measure of **deviation** of test results from their mean value, all determinations being carried out by one operator without change of apparatus in those cases where the manner of handling apparatus can alter results.

REPEATER. (1) A **repeating coil.** (2) A device for receiving, amplifying, and retransmitting a signal or wave. The application may involve telephone or telegraph lines, waveguides, or a complete radio receiver-transmitter (in which case reception is on one frequency and transmission on another, to prevent interference). In communicating over long lines the electrical pulses gradually become attenuated and often distorted so they must be built back to sufficient amplitude and correct shape to satisfactorily operate the receiving equipment. The restoration of these attenuated signals is the function of repeaters. In telegraph circuits various mechanical re-



Simple Telegraph Station

peaters are often used. One of the simplest is shown in the diagram. In this simple form communication is possible in one direction only, for the receiving station cannot break the circuit, as it would have to do in order to insert a key. A repeater station, more complicated than that diagrammed, can be installed to provide two-way telegraphy. Two repeaters having holding **coils,** and extra **batteries** are required in this system. These, however, do not restore the original spacing and shape of the pulses and the resulting signals may still give false operation of the receiving devices. In order to overcome this fault regenerative repeaters are used on many telegraph circuits, particularly on **teletype** or printing circuits. Moreover, in **digital** electronic **computers,** extensive use is made of fast-acting repeaters.

REPEATING COIL. A **transformer** (usually with a 1:1 ratio) employed in telephone lines to prevent conductive coupling between two line-sections.

REPELLER. See **klystron, repeller.**

REPETITIVE ERROR. The maximum deviation of the controlled variable in an **automatic controller** from the average value upon successive return to specified operating conditions following specified deviation therefrom.

REPLICA GRATING. The ruling of a diffraction **grating** is a complicated and expensive process. It has been found possible to flow certain plastic solutions over an original grating and, after the evaporation of the solvent, a film can be removed which has all of the lines of the grating impressed upon it. The techniques of making such replica gratings are not simple, but the cost is minor compared to that of an original grating.

REPRESENTATION OF A GROUP. If A_1, A_2, A_3, $\cdots$, A_n are **abstract elements** of a **group** G and $\mathbf{D}_1$, $\mathbf{D}_2$, $\mathbf{D}_3$, $\cdots$, $\mathbf{D}_n$ are square **matrices** forming a group **isomorphous** with G, then the matrices are n-dimensional matrix representations of G.

It is often possible to find a transformation $\mathbf{Q}^{-1}\mathbf{D}_i\mathbf{Q}$ so that each matrix is changed to the form

$$\begin{bmatrix} \mathbf{D}_i' & 0 \\ 0 & \mathbf{D}_i'' \end{bmatrix}$$

where $\mathbf{D}_i'$ is of order $m < n$ and $\mathbf{D}_i''$ is of order $(n - m)$. The representation is then said to be reducible. The process may be

repeated until no further reduction can be achieved. The representation has thus been completely reduced and is now irreducible.

REPRESENTATIVE OBSERVATIONS. Observations which give the true or typical meteorological conditions prevailing in an **air mass.**

REPRODUCER GROUP. A disc-record reproducing combination consisting of a single element reproducer with its supporting arm and equalizer equipment.

REPRODUCING SYSTEM, SOUND. A combination of transducing devices (see **transducer**) and associated equipment for reproducing recorded sound.

REPULSION, ELECTROMAGNETIC. See **electromagnetic repulsion.**

REPULSIVE FORCES. Forces between bodies which tend to move them apart. The existence of such forces between molecules is shown by their **collision diameters** and similar properties; while in the case of crystals these forces, in equilibrium with forces of attraction, result in the formation of a stable ionic system.

REPULSIVE FORCES IN LIQUIDS. The repulsive forces between molecules of a liquid decrease very rapidly with distance between the molecule centers, and are often approximated by an attractive force varying as a high negative power of the separation, e.g., a twelfth power. They are similar in origin to **covalent forces,** and accompany the increase in potential energy required to raise the electron density in the overlapping parts of the molecules.

REPULSIVE POTENTIAL. The force between two atoms keeping them apart at short distances is due to the overlapping of the electron clouds, especially of the closed shells of electrons. The potential, ϕ, may be approximately represented as a function of the internuclear distance, r, in many ways, the form

$$\phi = \frac{a}{r^n},$$

where n is usually about 10, being very convenient.

RE-RECORDING. The process of making a recording by reproducing a recorded sound source and recording this reproduction.

RE-RECORDING SYSTEM. An association of reproducers, mixers, amplifiers, and recorders capable of being used for combining or modifying various sound recordings to provide a final sound record. Recording of speech, music, and sound effects may be so combined.

RESET, DEGREE OF. The **reset flux level** expressed as a percentage or fraction of the reset flux level required to just prevent firing of the reactor (see **reactor (2)**) in the subsequent **gating** alternation under given conditions. (See **amplifier, magnetic** and following entries.)

RESET FLUX LEVEL. The difference in **saturable reactor** core **flux level** between the saturation level and the level attained at the end of the **resetting** alternation. (See **amplifier, magnetic** and following entries.)

RESETTING (PRESETTING). The action of changing **saturable reactor** core flux level to a controlled ultimate reset level which determines the gating action of the reactor during the subsequent gating alternation. The terms *resetting* and *presetting* are synonymous in common usage. (See **amplifier, magnetic** and following entries.)

RESETTING HALF-CYCLE. That half-cycle of the **magnetic amplifier** a-c supply voltage during which **resetting** of the **saturable reactor** may take place.

RESETTING INTERVAL. That interval of the cycle during which the **saturable reactor** core flux level is actually changing from the saturation level to the **reset flux level.** (See **amplifier, magnetic** and following entries.)

RESIDUAL BLUE. A phenomenon observed with white light scattered by small particles in suspension. Viewed through a suitably-oriented **Nicol prism,** the scattered light appears blue.

RESIDUAL INDUCTION (B_r). The **induction** in a magnetic sample after removal of a saturating **magnetizing force.** (See **hysteresis.**)

RESIDUAL RADIATION. When light or other radiation falls on the surface of a transparent body, part of it is reflected, part is transmitted, and part is absorbed. The **spectrum** of the transmitted portion, when compared with that of the original radiation, may reveal that certain sharply defined wavelength ranges have failed to get through, but does not indicate whether they have been absorbed or reflected.

Transparent media sometimes reflect very copiously those wavelengths whose absence from the transmitted radiation causes conspicuous absorption bands. Quartz, for example, reflects (or absorbs and re-radiates) **infrared radiation** of 8.5 microns and also that of 20 microns wavelength almost as well as a polished metal. Rock salt does the same at 50 microns. Rubens and Nichols devised an ingenious method of isolating beams of these infrared rays by reflection at polished surfaces of quartz or rock salt, the residue, after several reflections, called by them *Reststrahlen* (residual rays), being almost monochromatic. Analogous properties are exhibited in the visible spectrum by many aniline dyes, the selectively reflected light appearing as a "surface color" complementary to the transmitted portion.

RESIDUAL RANGE. See **range.**

RESIDUAL RESISTANCE. That part of the electrical resistance of a metal which is independent of the temperature, and hence remains when the resistance due to scattering of the electrons by lattice vibrations is made small at low temperatures (see **conductivity, electrical**). Residual resistance is caused by impurities and imperfections in the crystal, and hence may be reduced by purification, annealing, etc.

RESIDUE. If $f(z)$, a function of the **complex variable,** has a **pole** at $z = z_0$ so that it may be expanded in a **Laurent series** $\Sigma a_n(z - z_0)^n$, then the coefficient a_{-1} is the **residue** of the function at the point z_0. (See **calculus of residues.**)

RESIDUE THEOREM. See **calculus of residues.**

RESILIENCE. The resilience of a body measures the extent to which energy may be stored in it by elastic deformation. The implication of the word "stored" in the above definition is that this energy may be released in the form of mechanical work when the force causing the elastic deformation is removed, and that resilience is a property of a material within its proportional limit. The "modulus of resilience" is the maximum energy storage in a unit volume of the material. In practical units it is the inch pounds of energy stored in a cu. in. of the material stressed to the proportional limit **(elastic limit).** The modulus of resilience is directly proportional to the square of the stress, and inversely proportional to the modulus of elasticity.

RESISTANCE. The uses of this term in physics are in accordance with its general meaning of "that which tends to oppose motion". (1) Mechanical resistance is the opposition offered by a material body to forces which tend to produce motion. This mechanical resistance may arise from friction, from stresses set up in rigid anchors, or from inertia. Whenever the power dissipated in friction is proportional to the square of the velocity, mechanical resistance may be defined as the real part of **mechanical impedance,** the unit of which is the **mechanical ohm.** (2) Electric conductors are believed to contain free electrons, the movement of which through the substance constitutes **electric conduction.** In this migration the moving particles evidently meet with some restraint, since heat is generated. Electrical resistance is the factor by which the square of the instantaneous **conduction current** must be multiplied to give the power lost by dissipation as heat or other permanent radiation of energy away from the electric circuit. (Consider the "radiation resistance" of an antenna.) The unit of electrical resistance is the **ohm.** (3) Acoustic resistance is defined as the real component of **acoustic impedance,** the commonly-used unit being the **acoustic ohm.** Acoustic flow resistance (d-c acoustic resistance) is defined as the quotient of the pressure difference between the two surfaces of a sound-absorbing material by the volume current through the material. (4) Fluid resistance is the opposition offered by gases or liquids to the passage of bodies through them. (See **viscosity, fluid friction.**)

RESISTANCE, BLOCKED. See **blocked resistance.**

RESISTANCE BOX. A laboratory **resistor,** enclosed in a box, with provision for external adjustment.

RESISTANCE BOX, DIAL. A **resistance box** with dial switches allowing connection of the resistors in various combinations so that the resistance between the terminals may be varied in steps.

RESISTANCE BOX, PLUG. A **resistance box** whose individual resistors are connected to heavy metal blocks on the cover. Individual resistors are shorted by wedging metal plugs between adjacent blocks.

RESISTANCE BOX, POST OFFICE. See **post office box.**

RESISTANCE, BRONSON. See **Bronson resistance.**

RESISTANCE, EXTERNAL. The resistance of that part of the electric circuit which lies outside the source of the current, e g., the resistance of a wire and other apparatus connected externally between the poles of an electrolytic cell or cells

RESISTANCE, FLOW (D-C ACOUSTIC RESISTANCE). The quotient of the pressure difference between the two surfaces of a sound absorbing material, in dynes/cm^2, by the volume current through the material in cm^3/sec. The unit is the **acoustical ohm.**

RESISTANCE, FORCING. A resistance placed in series with a control winding of a **magnetic** or **dynamoelectric amplifier** to cause it to have a higher speed of response.

RESISTANCE, FOUR TERMINAL. A standard resistance having four points at which connection to an external circuit may be made. The two outer terminals are used to connect the resistance to the source of current; the potential difference across the two inner terminals may then be measured without interference due to variable resistance at the current terminals.

RESISTANCE, INTERNAL. The resistance within the apparatus which is generating an electric current; e.g , in a **cell,** the resistance of the **electrodes** and the electrolyte **solution.**

RESISTANCE, INTRINSIC ($\mathcal{R}$). The real part of intrinsic impedance. (See **secondary electromagnetic constants.**)

RESISTANCE, NEGATIVE. A negative resistance exists in a circuit when the derivative of voltage across the circuit with respect to the current through the circuit has a negative value.

RESISTANCE NOISE OR JOHNSON NOISE. See **noise, thermal.**

RESISTANCE PYROMETER OR THERMOMETER. The fact that the electrical **resistance** of a metal wire increases with rising temperature is the basis of a very useful class of instruments. One has only to calibrate a given length of wire, as to its resistance in relation to its temperature, enclose it in a suitable protecting tube, and keep it connected with the resistance-measuring **bridge,** to have a resistance thermometer adapted to a variety of uses over a very wide temperature range. The metal nearly always employed is platinum. The variation of resistivity with temperature of platinum is very nearly linear, being closely approximated by the formula $r = 0.000000037t + 0.000011$, in ohm-centimeters and centigrade degrees. Callendar found that for any given platinum resistance thermometer there is a slight systematic departure from this formula, characteristic of the particular sample of wire It is best, therefore, to calibrate each instrument throughout the range for which it is intended. (See **thermometry.**)

RESISTANCE, SPECIFIC (RESISTIVITY). A proportionality factor characteristic of different substances equal to the **resistance** that a centimeter cube of the substance offers to the passage of electricity, the current being perpendicular to two parallel faces. It is defined by the expression:

$$R = \rho \frac{l}{A}$$

where R is the resistance of a uniform conductor, l is its length, A is its cross-sectional area, and ρ is its resistivity. Resistivity is usually expressed in ohm-centimeters.

RESISTANCE, SPECIFIC ACOUSTIC. The real component of the specific acoustic impedance. (See **impedance, specific acoustic.**)

RESISTANCE, "SPREADING." In a point-contact **rectifier,** the effective series **resistance**

of the unit, which is not due to the resistance of the **barrier layer.**

RESISTANCE, STANDARD. A specially designed and constructed **resistor,** whose resistance is accurately-known and stable against **drift.**

RESISTIVE-WALL AMPLIFIER. An **electron-beam amplifier** in which the beam flows near a resistive wall. **Gain** is obtained through interaction between the stream-charge and the wall-charge, which is induced by the stream. The wall-charges act on the stream so as to cause larger and larger **bunches** to be formed, which result in exponential growth of the original signal with distance. Gain and gain-bandwidth are comparable to other forms of traveling wave tubes, and the **stability** is inherently greater.

RESISTIVITY. See **resistance, specific.**

RESISTOR. An element of apparatus used to offer **resistance** to an electric current.

RESISTOR, BALLAST. See **ballast tube.**

RESISTOR, BIFILAR. A **resistor** wound with a wire doubled back on itself, like a long, narrow hairpin, to reduce the **inductance.**

RESISTOR, CHAPERON. A **resistor** with a modified bifilar winding to reduce distributed capacitance as well as self-inductance.

RESISTOR, CURTIS WINDING. A type of **winding** designed to reduce residual inductance and capacitance. This is achieved by reversing the direction of alternate turns, by passing the wire through a diametral slot on a cylindrical coil form.

RESISTOR, THOMAS TYPE. Thomas standard resistors are wound of bare manganin wire, annealed in an inert atmosphere, and sealed in a dry, double-walled container. They are very stable against aging **drift,** and are used at the National Bureau of Standards to maintain the **ohm.**

RESISTOR, WENNER WINDING. A type of **winding** designed to reduce residual inductance and capacitance. Alternate turns are reversed in direction by looping them around a heavy, longitudinal cord.

RESISTOR, WOVEN-WIRE. A **resistor** having low capacitance and inductance, wound with a ribbon containing the resistance wire in a zigzag pattern.

RESNATRON. A high-power, high-efficiency, **cavity-resonator tetrode** designed to operate in the VHF region. Up to 60 KW, CW, efficiencies of 60% have been obtained. The principle of operation is similar to that of a **class C oscillator,** with careful attention to beam focusing playing a large part in the high efficiencies achieved. Cavities comprising the oscillating circuits are within the vacuum envelope, and are built integral with the electronic elements of the tube.

RESOLUTION. A term used in a number of specific cases in science to denote the process of separating closely-related forms or entities or the degree to which they can be discriminated. The term is most frequently used in optics to denote the smallest extension which a magnifying instrument is able to separate or the smallest change in wavelength which a spectrometer can differentiate. In this last sense, it is defined as the ratio of the average wavelength (wave number or frequency) of two spectral lines, which can just be detected as a doublet, to the difference in their wavelengths (wave numbers or frequencies). The term resolution is also applied to such varied processes as the separation of a racemic mixture into its optically-active components or as the breaking up of a vectorial quantity into components.

RESOLUTION CHART. A chart employed to check the linearity, definition, and contrast of **television systems.**

RESOLUTION, EFFECT OF INCREASING WAVELENGTH. Since the effect of increasing wavelength upon resolution is given by the relationship

$$\Delta\nu = -(\Delta\lambda)/\lambda^2,$$

where $\Delta\nu$ is the change in wave number corresponding to a change in wavelength $\Delta\lambda$, at a wavelength λ, therefore, the **resolving power** in wave number units increases rapidly for a given resolving power in wavelengths. For this reason, investigations in the **radiofrequency** region are important.

RESOLUTION OF MASS SPECTROMETER. The separation of adjacent peaks of a **mass spectrum** by a mass spectrometer.

RESOLUTION SENSITIVITY. The minimum change in the measured variable which produces an effective response of the instrument or automatic controller.

RESOLVER. Means for resolving a vector into two mutually perpendicular components.

RESOLVING POWER. (1) The ability of an optical system to resolve, i.e., separate, two entities, such as the ability of a **telescope** to separate the images of the two stars of a double star, the ability of a **microscope** to separate the images of two points which are close together, and the ability of a **spectroscope** to separate two spectral lines. Most studies of resolving power are based on the **Rayleigh criterion** of resolving power. (1a) The resolving power of a microscope is given by the relation $d = 1.22\,\lambda/2$ N.A., where d is the linear separation of two points, λ is the wavelength used, and N.A. is the **numerical aperture** of the object lens. (1b) Most telescopes have large objective lenses in order to have large light-gathering power, and to have high resolution. This high resolution may produce resolved images too close together to be resolved by the human eye. Hence an eye-lens or ocular is included in the system for the purpose of magnifying the initial image so that the eye can see it as resolved. Note that no amount of magnification of the initial image can increase the resolving power of the telescope over the resolving power of the objective lens. (2) By extension, the term applies to instruments separating particles. The resolving power of a **mass spectroscope** is the highest value of the ratio $m/\Delta m$ for the complete separation of the mass spectrum lines differing by Δm in mass (3) In a **unidirectional antenna,** the resolving power is the reciprocal of its **beam width,** measured in degrees. The resolution of a directional radio system can be different from the resolving power of its antenna, since the resolution is affected by other factors.

RESOLVING TIME (OF A RADIATION COUNTER). The time from the start of a counted **pulse** to the instant a succeeding pulse can assume the minimum strength to be detected by the counting circuit. (This quantity pertains to the combination of tube and recording circuit.)

RESONANCE. (1) Every physical system, in general, has one or more natural **vibration** frequencies characteristic of the system itself and determined by constants pertaining to the system. Thus a flexible string of length l and mass δ per unit length, and subjected to a tension f, will, if struck or plucked and left to itself, vibrate with frequencies equal to

$$\frac{1}{2l}\sqrt{\frac{f}{\delta}}$$

and to various integral multiples thereof (overtones). If such a system is given impulses with some arbitrary frequency, it will necessarily vibrate with that frequency even though it is not one of those natural to it. These "forced vibrations" may be very feeble; but if the impressed frequency is varied, the response becomes rapidly more vigorous whenever any one of the natural frequencies is approached, its amplitude often increasing many fold as exact synchronism is reached. This effect is known as resonance. The many uses of this conception in present-day physics stem from this initial use in mechanics or acoustics to denote a prolongation or reinforcement of sound by induced vibration. Such acoustical (and mechanical) resonance can often be represented by a differential equation of the form

$$M\frac{d^2x}{dt^2} + R\frac{dx}{dt} + Sx = A\cos\omega t$$

which permits a mathematical statement of velocity resonance and displacement resonance (see **resonance, velocity** and **resonance, displacement**) as shown in the following table. (2) Electrical resonance is a condition which tends to produce relatively great currents in reactive circuits. There are two types, series resonance and parallel resonance, as explained in the following discussion. In an a-c circuit containing inductance and capacitance in series the impedance is given by

$$Z = R + j\left[\omega L - \frac{1}{\omega C}\right]$$

where R is the resistance, ω is 2π times the frequency, L is the inductance, and C, the capacitance. It can readily be seen that at some frequency the terms in the brackets will cancel each other, and the impedance will equal the resistance alone. This condition, which gives a minimum impedance (and thus

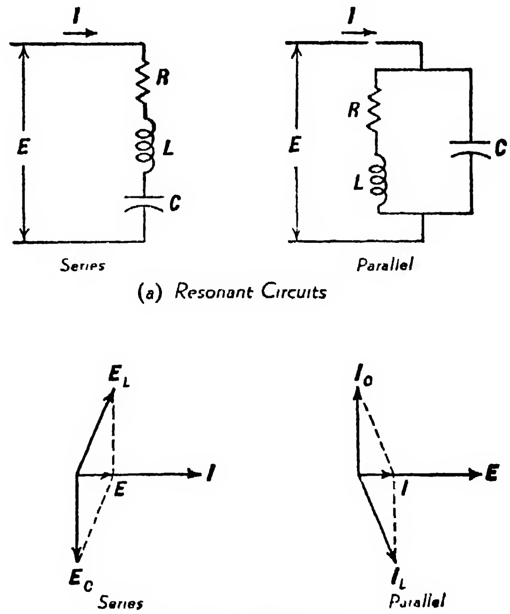
Table of Properties of Resonant Systems

$$M\frac{d^2x}{dt^2} + R\frac{dx}{dt} + Sx = A\cos\omega t$$

	At Velocity Resonance	At Displacement Resonance	At the Natural Frequency
Frequency	$\frac{1}{2\pi}\sqrt{\frac{S}{M}}$	$\frac{1}{2\pi}\sqrt{\frac{S}{M}-\frac{R^2}{2M^2}}$	$\frac{1}{2\pi}\sqrt{\frac{S}{M}-\frac{R^2}{4M^2}}$
Amplitude of displacement	$\frac{A}{R\sqrt{\frac{S}{M}}}$	$\frac{A}{R\sqrt{\frac{S}{M}-\frac{R^2}{4M^2}}}$	$\frac{A}{R\sqrt{\frac{S}{M}-\frac{3R^2}{16M^2}}}$
Amplitude of velocity	$\frac{A}{R}$	$\frac{A}{R\sqrt{1+\frac{R^2}{4MS-2R^2}}}$	$\frac{A}{R\sqrt{1+\frac{R^2}{16MS-4R^2}}}$
Phase of displacement with reference to applied force	$\frac{\pi}{2}$	$\tan^{-1}\sqrt{\frac{4MS}{R^2}-2}$	$\tan^{-1}\sqrt{\frac{16MS}{R^2}-4}$

For values of R, small compared to $\sqrt{SM}$, there is little difference between the three cases discussed above.

a maximum current for a fixed impressed voltage) and unity power factor is known as series resonance. Where the resistance is small the current may become quite large. As the voltage drop across the **condenser** or **coil** is the product of the current and the impedance of that particular unit it may also become very large. The condition of resonance may even give rise to a voltage across one of these units which is many times the voltage across the whole circuit, being, in fact, Q times the applied voltage for the condenser and nearly the same for the coil. This is possible since the drops across the coil and condenser are nearly 180° out of phase and thus almost cancel one another, leaving a relatively small voltage across the circuit as shown in Fig 1*b*. For a circuit composed of an inductance unit in parallel with a capacitance the opposite effects of these two types of reactance will counteract one another at some frequency and produce unity power factor for the circuit. This is parallel resonance or antiresonance as it is sometimes called. In such a circuit the currents in the individual branches may be many times that in the line since they are out of phase and combine vectorially to give the line current. The impedance of a parallel resonant circuit is very high, its behavior being almost identical with that of the current in a series circuit if the Q of the parallel circuit is above 10. Fig 2 shows a typical frequency-response curve for resonant circuits, the ordinates being current for a series and impedance for a parallel resonant circuit. In series resonance the resonant condition is given exactly by the following expression



(a) Resonant Circuits

(b) Vector Relations

Fig 1

which also holds for parallel resonance if the Q is high:

$$\omega L = 1/\omega C.$$

Both types of resonance are widely used in communication circuits to select certain frequencies in preference to others. An example

is the tuning circuit of the radio **receiver.** (3) Resonance phenomena are exhibited by all systems in motion, including molecular,

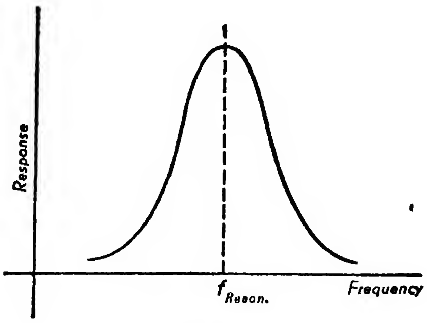


Fig. 2

atomic and electronic systems. The approach of quantum mechanics clarifies the behavior of such systems (see **resonance, quantum-mechanical**). See also the discussions of **resonance level; resonance radiation** and **resonance spectral lines.** (4) Another resonance phenomenon involving electrons or atomic nuclei is magnetic resonance (see **resonance, magnetic;** and **nuclear magnetic resonance**).

(5) The term resonance is often used adjectivally. (See **resonant.**)

RESONANCE ABSORPTION, NUCLEAR AND ELECTRONIC SPIN. The selective absorption of **electromagnetic energy** by a system of free particles possessing spin, when the energy of the radiation is equal to the spacing between the **Zeeman components** of a single spectral level.

RESONANCE ABSORPTION (NUCLEAR REACTOR). The absorption of neutrons with energies corresponding to a nuclear resonance level of the absorber. Sometimes used for absorption of all **neutrons** but thermal neutrons. (See **neutrons, thermal.**)

RESONANCE, AMPLITUDE. See **oscillation, forced.**

RESONANCE CAPTURE. The capture of an incident particle into a **resonance level** of the resultant compound nucleus. Resonance capture is characterized by having a large probability **(cross section)** at and very close to the **resonance energy** involved, in comparison with energies somewhat removed from the resonance energy.

RESONANCE, DRIVING-FORCE. See **resonance frequency.**

RESONANCE, DISPLACEMENT. Displacement **resonance** exists between **a** body, or a system, and an applied sinusoidal force if any small change in frequency of the applied force causes a decrease in the amplitude of displacement. (See table under **resonance;** and **oscillation, forced.**

RESONANCE ENERGY. The kinetic energy, measured with reference to the **laboratory system,** of a particle that will be captured or scattered preferentially because of the presence of an appropriate **resonance level** in the compound nucleus (incident particle plus target nucleus). The relation of the resonance energy E_{res} to the energy of excitation E_{exc} of the resonance level above the ground state of the compound nucleus is given by the expression

$$E_{res} = (E_{exc} - E_B)\frac{\text{mass of compound nucleus}}{\text{mass of target nucleus}}$$

where E_B is the binding energy of the incident particle in the compound nucleus.

RESONANCE ESCAPE PROBABILITY (NUCLEAR REACTOR). For a neutron slowing down without leakage, the resonance escape probability between two energies is the probability that a neutron at the higher energy will reach the lower energy, rather than be absorbed.

RESONANCE, FERMI. See **Fermi resonance.**

RESONANCE, FERROMAGNETIC. See **ferromagnetic resonance.**

RESONANCE FLUORESCENCE. Also called resonance radiation. The emission by an excited atom of a **radiation** of the same frequency as the exciting radiation.

RESONANCE FREQUENCY. (1) For a general discussion of resonance frequency, see **forced oscillations.** (2) A frequency for which some measure of the **response** of a circuit element is maximum (or minimum). Thus amplitude resonance occurs at that frequency for which a given amplitude stimulus yields a maximum amplitude response, phase resonance occurs when the response is in phase with the stimulus (i.e., at the frequency yielding zero reactance), and period resonance occurs when the driving-force frequency is the natural frequency of the circuit element. (3) The frequency of a mode of **elastic vibration**

of a crystal such as quartz, which is coupled through the **piezoelectric effect** to an electrical system.

RESONANCE FREQUENCY OF A CAPACITOR. A (physical) **capacitor** possesses not only capacitance, but also inductance and resistance. At high frequencies, the inductance of the terminal leads becomes important, and results in **series resonance** at some frequency.

RESONANCE LAMP. If the light from a quartz mercury arc is arranged to strike an evacuated quartz bulb containing a drop of mercury the **resonance line** (λ2537) is absorbed by the mercury vapor so that little or no radiation passes through the vapor directly. However, the bulb now acts as a source of radiation of the pure resonance line. Such sources are called resonance lamps. (See **resonance fluorescence.**)

RESONANCE LEVEL (NUCLEAR). An excited level of the compound system capable of being formed in a collision between two systems (e.g., between a nucleon and a nucleus). In a plot of **cross section** versus energy, there will usually be a maximum corresponding to each resonance level. (See **resonance energy.**)

RESONANCE, MAGNETIC. When a substance containing unpaired nuclear or electronic spin or orbital magnetic moments is placed in a strong magnetic field, its energy levels are split into two or more levels, depending on the orientation of the magnetic moment to the field. An oscillatory magnetic field at right angles to the constant field can then induce transitions between these levels, if the frequency of oscillation satisfies the quantum condition for the energy separation of the levels (cf. **Zeeman effect**). The transitions may be observed by the energy absorbed from the oscillating field at the resonance frequency. The pattern of resonance lines (in practice, the frequency is kept constant, and the strong field varied slowly) has been interpreted in a wide range of **paramagnetic salts** in determinations of **nuclear magnetic moments,** in studies on impurities in solids, etc.

RESONANCE NEUTRONS. See **neutrons, resonance.**

RESONANCE, NONLINEAR. Provided the dissipation of the system is low, the curve of the response (e.g., rms value) to a driving force, of a double energy-storage, passive system containing at least one nonlinear energy storage element, may be double-valued over a certain range, when plotted against the independent variable of driving force, or frequency, or one of the system parameters. Such a system is said to be in nonlinear resonance, if the operating point is on the upper leg of this double-valued response curve, and if the lowest-frequency component of the response is of the same frequency as the fundamental frequency of the driving force. If the circuit parameters or the excitation or both preclude the existence of a double-valued response, the system is said to be in nonlinear resonance if the operating point is in that range of the curve of response (e.g., rms value) versus driving force, in which the slope of the curve is greater than the slope in the vicinity of the origin. (See also **ferroresonance.**)

RESONANCE OF TUBES. The increase in the average sound energy density in a tube because of the reinforcement of sound waves traveling in opposite directions with proper phase relations. The fundamental resonant frequency of a tube open at both ends is equal to $c/2l$, where c is the velocity of sound in cm/sec, and l is the length of the tube in cm. For a tube open at one end only, the corresponding resonant frequency is equal to $c/4l$. Both expressions are approximate, being subject to small corrections for the cross-sectional size of the tube.

RESONANCE, PHASE. See **resonance frequency.**

RESONANCE, π MODE OF. In **traveling-wave megnetrons,** the **mode** in which the instantaneous phase-difference between adjacent segments is π radians.

RESONANCE, QUANTUM MECHANICAL. In the theory of **valence bonds** it is often possible to envisage two or more alternative arrangements of the bonds between the atoms in a molecule, both arrangements being of the same energy because of the symmetry of the geometrical configuration. Thus, for example, in the benzene ring, there are two obvious ways of putting in the three double bonds. But such **degenerate states,** in quantum theory, may always be combined, in any proportions. In fact, there will usually be further

interaction terms, such as the **coulomb energy** between the bonding electrons, which will tend to stabilize a mixture of the two states, at a lower energy than either separately. One then says that the energy of the system is lowered by "resonance" between the two alternative arrangements of the bonds. (See also **exchange energy.**)

RESONANCE RADIATION. A process of re-emission of radiation by gases and vapors. The process involves excitation, by incident photons, of atoms to higher energy levels, from which they may return to the ground state, or to other states. Therefore the radiation emitted, while characteristic of the particular atom, is not necessarily of the same frequency as that absorbed. Resonance radiation appears to be a species of **fluorescence,** except that it may take place with no change in frequency. For example, Wood found that sodium vapor, upon absorption of D-light (16.973 cm^{-1}), re-emitted the same frequency and therefore the name resonance radiation was adopted. But when Strutt excited sodium vapor by light of wave number 30 273 cm^{-1} (second line of the principal sodium series), the emitted radiation was D-light (16.973 cm^{-1}).

RESONANCE SCATTERING. See **scattering, potential.**

RESONANCE, SERIES. See **resonance,** for the application of the term to electric circuits; see **spectrum, resonance,** for the application of the term to spectra

RESONANCE SPECTRAL LINES (FIRST, SECOND, ETC). The spectral lines emitted when an electron undergoes transfer to its normal energy state in a given atom from its next highest energy state (first resonance line), or from its next-but-one highest energy state with allowed transition to the ground state (second resonance line), etc. These resonance transitions correspond to the first, second, etc., resonance potentials, and may be assumed to be single lines only when no account is taken of **fine structure, hyperfine structure** and other complications.

RESONANCE, VELOCITY (PHASE RESONANCE). Velocity resonance exists between a body, or system, and an applied sinusoidal force if any small change in the frequency of the applied force causes a decrease in velocity at the driving point; or if the frequency of the applied force is such that the absolute value of the driving-point impedance is a minimum. (See **impedance, driving-point;** see also table under **resonance.**)

RESONANT. This adjective is often replaced by the adjectival noun, **resonance.**

RESONANT CHAMBER. A **resonator.**

RESONANT-CHAMBER SWITCH. A waveguide switch which diverts power from one guide to another by detuning a **cavity resonator** of high **Q** in the branch which is to refuse the power. (See **window, resonant.**)

RESONANT DIAPHRAGM. See **window, resonant.**

RESONANT FREQUENCY. (1) A frequency at which **resonance** exists. The commonly used unit is the cycle per second. In cases where there is a possibility of confusion, it is necessary to specify the type of resonant frequency, e g , displacement resonant frequency or velocity resonant frequency. (2) The frequency of a mode of elastic vibration of a crystal such as quartz, which is coupled through the **piezoelectric effect** to an electrical system.

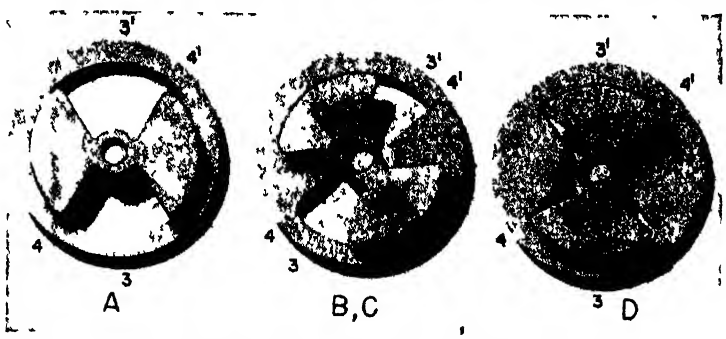
RESONANT IRIS. A form of resonant window (especially a circular **waveguide**) so called because of its similar appearance to an optical **iris.** (See **window, resonant.**)

RESONANT-IRIS SWITCH. A waveguide switch which diverts power from one guide to another by detuning a **resonant iris** inserted in the branch which is to refuse the power. (See **window, resonant.**)

RESONANT WINDOW. See **window, resonant.**

RESONANT-LINE OSCILLATOR. See **oscillator, resonant-line.**

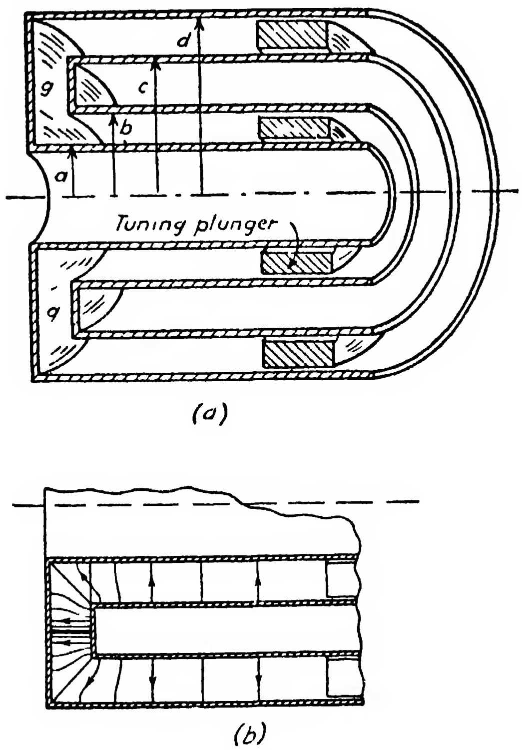
RESONANT MODE, $TE_{m,n,p}$ (IN CYLINDRICAL CAVITY). In a hollow metal cylinder closed by two plane metal surfaces perpendicular to its axis, the **resonant mode** whose transverse field pattern is similar to the $TE_{m,n}$ wave in the corresponding **cylindrical waveguide,** and for which p is the number of half-period field variations along the axis. When the cavity is a rectangular parallelopiped, the axis of the cylinder from which the cavity is assumed to be made should be designated, since there are three such axes possible.



Stator and rotor plates of the butterfly tuning circuit. Capacitance and inductance between points 1 and 2 on the stator are at maximum in A and minimum in D. (Courtesy General Radio)

RESONATOR. (1) A device used to utilize or exhibit the effects of **resonance.** (2) A group of electrons which absorbs electromagnetic radiation of certain frequencies.

RESONATOR, ANNULAR. A **resonator** which can be considered to be formed from a



Structure (*a*) and electric-field configuration (*b*) of annular resonator (By permission from 'Microwave Theory and Techniques' by Reich et al. Copyright 1953, D. Van Nostrand Co., Inc.)

short-circuited, half-wavelength, coaxial-line resonator by folding one end back upon the other. More exactly, because of the sharp corners in the region of the antinode of electric field, the annular resonator is equivalent to a half-wavelength, coaxial resonator with a small shunting capacitance at its midpoint.

RESONATOR, BUTTERFLY. A lumped-parameter **resonator** derived from a conventional, variable capacitor. Magnetic coupling has been added by the two arms 3 and 3'. Both electric and magnetic coupling vary as a function of rotor position. (See above figure.)

RESONATOR, CAVITY. A closed section of **coaxial line or waveguide,** completely enclosed by conducting walls. The shape of cavity resonators is governed by such considerations as the desired values of **resonance frequency, shunt conductance,** and **Q;** by the purpose for which they are to be used, and by the manner in which they are to be tuned.

RESONATOR, COAXIAL-LINE. A **resonator** consisting of a section of coaxial line short-circuited on one end ($\lambda/4$ long), or both ends ($\lambda/2$ long). Short-circuiting plungers to change the resonator length, or lumped capacitance across a point of high electric field strength may be used to change the frequency of **resonance.**

RESONATOR, COMPOUND. A resonator (see **resonator (1)**) consisting of two or more acoustic resonators coupled together.

RESONATOR, COMPOUND, BOYS TYPE. A long open, cylindrical tube, coupled at one end to a **Helmholtz resonator.**

RESONATOR, CYLINDRICAL CAVITY. The lowest resonance frequency of a circular cylindrical cavity in a perfect conductor is

$$f_0 = \frac{V}{1.31d}$$

where $V = c/\sqrt{\mu\epsilon}$ is the electromagnetic velocity in the medium filling the cavity, and d is the cavity diameter.

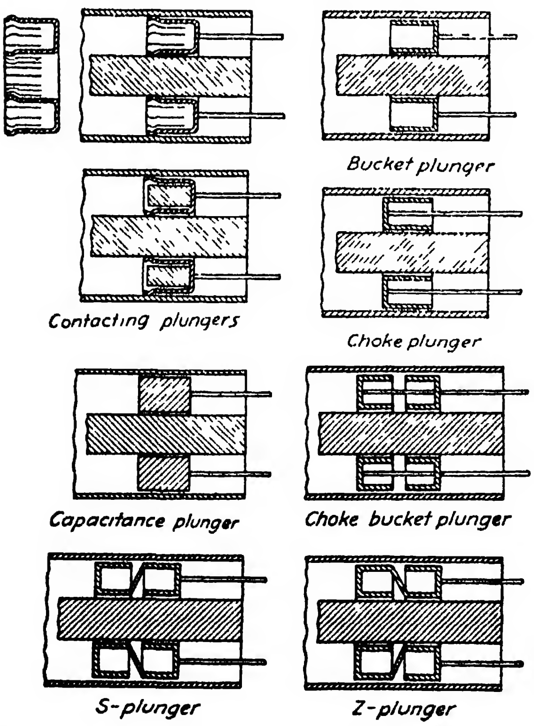
RESONATOR AND LONG LINE, FREQUENCY HYSTERESIS OF. Discontinuous changes in frequency as an **oscillator** is continuously tuned, due to the **long-line effect.**

RESONATOR, LONG-LINE EFFECT ON. See **long-line effect.**

RESONATOR, MICROWAVE. A **resonator** employed at **microwave frequencies.**

RESONATOR, PARALLEL-WIRE. A section of a parallel-wire **transmission line** most commonly operated with one end of the line terminated in the tube-electrodes, and the other end short-circuited. (See also **Lecher wires.**)

RESONATOR(S), TYPES OF PLUNGERS FOR. The frequency of resonance of microwave resonators (see **resonator, microwave**) is changed by means of movable plungers, which change the effective length of the resonator. The contacting plunger has slotted fingers to form a low, ohmic short circuit at the point of contact. A capacitance plunger effectively short-circuits the resonator by presenting a large capacitance whose position is controllable. It does not contact the resonator walls. More complicated non-contacting plungers such as the choke, bucket, S-plunger, Z-plunger, and possible combinations of these are used to lower further the short-circuit impedance, and the power lost past the plunger.



Types of plungers for resonators (By permission from "Microwave Theory and Techniques" by Reich et al., Copyright 1953, D. Van Nostrand Co., Inc.)

RESONATOR, WAVEGUIDE. See **waveguide resonator.**

RESORPTION. The **absorption,** or less commonly, the **adsorption** by a body or system of material previously released from absorption or adsorption by that same body or system.

RESPONSE. Of a device or system, a quantitative expression of the output as a function of the input under conditions which must be explicitly stated. The response characteristic, often presented graphically, gives the response as a function of some independent variable, such as frequency or direction Modifying phrases must be prefixed to the term "response" to indicate explicitly what measure of the output or of the input is being utilized

RESPONSE, AVAILABLE POWER. Of an electroacoustic **transducer** used for sound emission, the ratio of the mean-square sound pressure (see **sound pressure, mean-square**) apparent at a distance of 1 meter in a specified direction from the effective acoustic center of the transducer to the available electric power from the source. The available power response is usually expressed in decibels above the reference response of 1 microbar squared per watt of available electric power The sound pressure apparent at a distance of 1 meter is determined by multiplying the sound pressure observed at a remote point where the sound field is spherically divergent by the ratio of the distance of that point, in meters, from the effective acoustic center of the transducer, to the reference distance of 1 meter. The available power response is a function not only of the transducer but also of some source impedance, either actual or hypothetical, the value of which must be specified.

RESPONSE, FREE-FIELD CURRENT (RECEIVING CURRENT SENSITIVITY). Of an electroacoustic transducer used for sound reception, the ratio of the current in the output circuit of the **transducer** when the output terminals are shortcircuited to the free-field sound pressure existing at the transducer location prior to the introduction of the transducer in the sound field. The free-field current response is usually expressed in decibels, viz., 20 times the logarithm to the base 10 of the quotient of the observed ratio divided by the reference ratio, usually 1 ampere per microbar. The free-field response is defined for a plane progressive sound wave whose direction of propagation has a specified orientation with respect to the principal axis of the transducer.

RESPONSE, FREE-FIELD VOLTAGE (RECEIVING VOLTAGE SENSITIVITY). Of an electroacoustic **transducer** used for sound reception, the ratio of the voltage appearing at the output terminals of the transducer when the output terminals are open-circuited to the free-field sound pressure at the transducer location prior to the introduction of the transducer in the **sound field.**

RESPONSE RATIO, SPURIOUS. The ratio of (1) the field strength at the frequency which produces the spurious response to (2) the field strength at the desired frequency, each field being applied in turn, under specified conditions, to produce equal outputs. Image ratio and intermediate frequency response ratio are special forms of spurious response ratio.

RESPONSE, RELATIVE. The ratio, usually expressed in decibels, of the **response** under some particular conditions to the response under reference conditions, which should be stated explicitly

RESPONSE TIME OF A MAGNETIC AMPLIFIER. The period of time required for a change of average output current of 63 per cent of the total change. Response time should be specified for operation of the magnetic amplifier at its rating, except for control currents and output currents. The output current should change between the rated value and a lower value. Unless otherwise specified, the lower value shall be zero where possible. Otherwise, it shall be minimum output plus 10 per cent of the difference between rated and minimum output. The signal shall be that step change of voltage which yields these values of output current. The response time specified shall be the maximum which exists for any condition within the rating (e.g., such effects as growth or decay, time phase of signal application, temperature). The 95 per cent response time of a magnetic amplifier is that period of time required for a change of output of 95 per cent of total change, under the conditions and limits given in the definition of response time.

RESPONSE, TRANSMITTING CURRENT. Of an electroacoustic **transducer** used for sound emission, the ratio of the **sound pressure** apparent at a distance of 1 meter in a specified direction from the effective acoustic center (see **acoustic center, effective**) of the transducer to the current flowing at the electric input terminals. The transmitting current response is usually expressed in decibels above a reference current response of 1 microbar per ampere The sound pressure apparent at a distance of 1 meter is determined by multiplying the sound pressure observed at a remote point where the sound field is spherically divergent by the ratio of the distance of that point in meters, from the effective acoustic center of the transducer, to the reference distance of 1 meter

RESPONSE, TRANSMITTING POWER (PROJECTOR POWER RESPONSE). Of an electroacoustic **transducer** used for sound emission, the ratio of the mean-square sound pressure (see **sound pressure, mean-square**) apparent at a distance of 1 meter in a specified direction from the effective acoustic center (see **acoustic center, effective**) of the transducer to the electric power input. The transmitting power response is usually expressed in **decibels** above a reference response of 1 microbar squared per watt of electric power input.

RESPONSE, TRANSMITTING VOLTAGE. Of an electroacoustic **transducer** used for sound emission, the ratio of the sound pressure apparent at a distance of 1 meter in a specified direction from the effective acoustic center (see **acoustic center, effective**) of the transducer to the signal voltage applied at the electric input terminals. The transmitting voltage response is usually impressed in

decibels above a reference voltage response of 1 microbar per volt.

RESPONSIVENESS, ACOUSTIC. The reciprocal of the acoustic resistance. (See **resistance, acoustic.**)

REST DENSITY OF A FLUID. The local density of a fluid in a **Lorentz frame** in which the fluid is locally at rest.

REST FRAME. Lorentz frame in which the total momentum of a system vanishes.

REST MASS. The mass m_0 of a particle in the system in which it appears to be at rest. It is the mass in the classical, or Newtonian sense; that is, it does not include the additional mass which, according to the **relativistic mass equation,** is acquired by a particle or body when set in motion. If the particle is annihilated, an amount m_0c^2 of energy is released.

RESTING FREQUENCY. The **center frequency** or **carrier frequency** of a **frequency-modulation transmitter.**

RESTORER, D-C. See **d-c restorer.**

RESTRICTED INTERNAL ROTATION. Restriction of the free rotation of the molecules or parts of molecules in some substances, e.g., solid methane, at certain temperatures, leading to anomalies in the specific heat. The origin of the restricting potentials is uncertain. Also referred to as *hindered rotation.*

RESTSTRAHLEN. See **residual radiation.**

RESULTANT. An entity or quantity obtained by means of (or as the result of) a given process. Thus, the resultant of a system of forces is the single force that has the same effect.

RETARDED FIELDS. Electromagnetic field strengths **E**, **B** at a point **r** at time t derived from the **retarded potentials,** i.e., generated by charges and currents that were at **r** − **R** at time

$$t - \frac{|\mathbf{R}|}{c} \text{ (all } \mathbf{R}\text{).}$$

RETARDED POTENTIALS. The electromagnetic potentials at a point **r** at time t due to sources at the points **r** − **R** at times

$$t - \frac{|\mathbf{R}|}{c},$$

i.e., on the past **light cone** through the event **r**, t.

RETARDATION COIL. An **inductor** used in telephone circuits to block audio-frequency signals, while offering little opposition to d-c signals.

RETARDING-FIELD (POSITIVE - GRID) OSCILLATOR. See **oscillator, retarding-field (positive-grid) oscillator.**

RETENTIVITY (B_{rs}). That property of a magnetic material which is measured by the residual induction (see **induction, residual)** when a saturating **magnetizing force** is removed (See **hysteresis.**)

RETGERS, LAW OF. The physical properties of isomorphous mixtures (mixed crystals) are continuous functions of the percentage composition.

RETICULAR DENSITY. The number of points per unit area in a network, as in that of a plane in a crystal lattice.

RETICLE. A network of fine lines, wires, or the like placed in the **focus** of the **objective** of a **telescope** or other optical instrument.

RETICULATED. Having the form of a network.

RETINA. The complicated back surface of the eye, in which light is changed to nerve impulses.

RETMA. Abbreviation for Radio-Electronics-Television Manufacturers' Association.

RETMA COLOR CODE. The system of identifying the magnitude, tolerance, and voltage ratings of small electronic components, such as capacitors and resistors, by the use of different-colored dots or bands.

RETRACE LINE. The line traced by the **electron beam** in a **cathode-ray tube** in going from the end of one line or field to the start of the next line or field.

RETROACTION. See **feedback.**

RETRODIRECTIVE MIRROR. A beam of light lying in a plane normal to the two sides of a right-angled dihedral angle with reflecting sides will be reflected parallel to its original path (antiparallel) no matter what its original direction. A beam of light entering

a trihedral angle with mutually-perpendicular reflecting sides, will be reflected back parallel to its original path (antiparallel) no matter what its original direction. Such a mirror is called retrodirective.

This idea may be used to check the right angle of a right-angled **prism** having a polished hypotenuse, with very high accuracy and without any standard right-angle for comparison, since only if the angle is exactly 90° will the reflected beam be exactly parallel with the initial beam.

RETURN INTERVAL. See **interval, return.**

RETURN LOSS. (1) At a **discontinuity** in a transmission system, the difference between the power incident upon the discontinuity and the power reflected from the discontinuity. (2) The ratio in **decibels** of the power incident upon the discontinuity to the power reflected from the discontinuity.

RETURN RATIO, FEEDBACK. The same as **loop gain.**

RETURN TRACE. The path of the **scanning spot** during the return interval. (See **interval, return; retrace line.**)

REVERSED FEEDBACK AMPLIFIER. See **amplifier, negative-feedback.**

REVERSIBLE CELL. See **cell, reversible.**

REVERSIBLE ELECTRODE. See **electrode, reversible.**

REVERSIBLE PATH. Path along which a system moves such that at any point the direction can be reversed by an infinitesimal change in the thermodynamical coordinates of the system.

REVERSIBLE PROCESSES. Some physical processes are of such a nature that if they are made to take place backward, that is, to go through the same stages in reverse order, the corresponding transfers of energy at each stage are reversed in direction but not in amount. Such processes are briefly characterized as "reversible." Thus a gas may have its density ρ and pressure p increased without any change in temperature (an isothermal compression). This is shown by the curve AB in Fig. 1. It necessitates the removal of heat exactly as fast as it is generated by the work of compression. The process may, in theory at least, be duplicated in reverse, so that BA coincides with AB, by allowing the gas to expand and restoring the withdrawn heat energy just as fast as needed to keep the temperature constant. Each change of a **Carnot cycle** is likewise reversible.

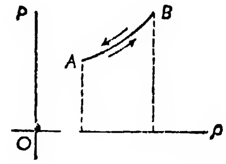


Fig. 1. Reversible pressure - density change in a gas

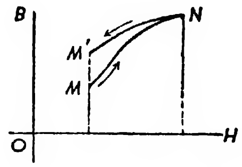


Fig. 2. Irreversible induction - intensity change in iron

On the other hand, consider the magnetization of iron, represented by the B-H (induction-intensity) curve MN in Fig. 2. If, after increasing the magnetization of iron until its condition reaches the stage N, the intensity of the magnetizing field is reduced, no amount of care will avail to make the curve retrace itself. The iron persists in retaining some of the energy that was imparted to it, and returns along NM' to a condition, represented by M', of higher magnetic induction than at first. Magnetizing iron is therefore an irreversible process.

REVERSIBLE TRANSDUCER. See **transducer, reversible.**

REVERBERATION. The persistence of sound at a given point, after direct reception from the source has stopped. This may be due (a) (as in the case of rooms) to repeated reflections from a small number of boundaries or to the free decay of the normal modes of vibration that were excited by the sound source; (b) (as in the case of underwater sound in the ocean) to scattering from a large number of inhomogeneities in the medium or reflection from bounding surfaces.

REVERBERATION CHAMBER. An enclosure in which all of the surfaces have been made as sound-reflective as possible. Reverberation chambers are used for certain acoustic measurements.

REVERBERATION TIME. For a given frequency, the time required for the average sound-energy density, originally in a steady state, to decrease after the source is stopped to one-millionth of its initial value (60 db).

Usually the pressure level for the upper part of this range is measured and the result extrapolated to cover 60 db.

REVERSAL TEMPERATURE. When light from a source giving a continuous spectrum, such as a black body, carbon arc or incandescent lamp, is passed through a luminous gas and analyzed by a spectrograph, the spectral lines of the gas will appear as bright or dark lines, depending on whether the black-body temperature of the source is below or above a certain critical temperature, called the reversal temperature, at which the lines disappear against the continuous background. This temperature is characteristic for a given spectral line, unless there is statistical equilibrium for all the different excited states in the gas.

REVERSIBILITY, MICROSCOPIC. See **microscopic reversibility, principle of.**

REVERSIBILITY, PRINCIPLE OF. If all parts of a beam of light are reflected directly back on themselves, no matter how many reflections or refractions it has undergone, the light will travel back over the identical path (or paths) it followed before reversal.

REYNOLDS AND MOORBY METHOD FOR MECHANICAL EQUIVALENT OF HEAT. The dissipating device in this method is a **Froude hydraulic brake** through which water passes in continuous flow. Water enters the brake at 0°C and leaves it at close to 100°C. From the amount of water passing per unit time and its rise in temperature, the amount of heat generated is determined.

REYNOLDS CRITERION. In geometrically-similar flow systems in which the boundary conditions may be fully expressed in terms of a scale length and a scale velocity, the condition that a laminar flow shall be stable or unstable to small disturbances is that the **Reynolds number** of flow should lie within a certain range. Many flows are stable for all Reynolds numbers below a critical value. In a classical series of experiments, Osborne Reynolds found the critical Reynolds number for pipe flow to be nearly 2000.

REYNOLDS NUMBER. The Reynolds number of a flow is defined as the product of a scale velocity and a scale length divided by the kinematic viscosity of the fluid. Reynolds numbers are only comparable when they refer to geometrically-similar flows, e.g., flow past spheres of various radii in different fluids at different speeds, and then, provided all the boundary conditions can be described by the scale velocity and scale length, flows of the same Reynolds number are dynamically similar.

For fluid flow in a pipe, the Reynolds number is given by the expression $VD\rho/\mu$, where V is the mean velocity of the fluid, ρ, its density, μ, its viscosity, and D the diameter of the pipe.

R-F. The frequently-used abbreviation for **radio frequency.**

RFC. An abbreviation for **radio-frequency choke.**

RHE. The absolute unit by which **fluidity** is measured or expressed. It is the reciprocal centipoise, which is in turn, one-hundredth of the **poise,** the c g s. unit of viscosity. One poise is equal to one dyne second per square centimeter.

RHEOSTAT. A variable **resistor** used for operation or control of electrical equipment. Rheostats might be classified as metallic, carbon, and electrolytic types. The most common form is the metallic type, in which the resistor is in the form of a metal wire or ribbon, or cast grid, these being made of a metal having poor conductivity, and little deterioration from heating The variable resistance of metallic rheostats is obtained by bringing out taps from different points of the resistance wire to the points of a multi-pointed switch which can be used to short-circuit different sections of the resistor Laboratory rheostats are frequently coils of resistance wire wound closely on an insulating cylinder and provided with a sliding contact finger which will bear on the wires themselves, and which can be employed to short-circuit any desired number of turns of the resistance wire.

RHEOTRON. A **betatron.**

RHENIUM. Metallic element. Symbol Re. Atomic number 75.

RHEOLOGY. The study of the flow of materials, particularly plastic flow of solids and the flow of non-Newtonian liquids.

RHEOPEXY. A property exhibited by certain **sols** containing rod-like or plate-like particles (such as bentonite and other clay suspensions), which consists in accelerated setting to the **gel** form brought about by any mechanical means that will facilitate the orientation of the particles.

RHM. A proposed unit of γ-ray source strength which is of such a magnitude that a one "rhm" source will produce one **roentgen** per hour at a distance of one meter.

RHO. (1) Density (mass per unit volume) (ρ). (2) Linear mass density (ρ). (3) Volume electric charge density (ρ). (4) The rhe, unit of fluidity (ρ). (5) Radius of curvature (ρ). (6) Reflectance (ρ). (7) Reflectivity (ρ'). (8) Resistivity, or specific resistance (ρ). (9) Vapor density (ρ). (10) Absolute humidity (ρ).

RHODIUM. Metallic element Symbol Rh. Atomic number 45.

RHOMB, FRESNEL. See **Fresnel rhomb.**

RHOMBIC ANTENNA. See **antenna, rhombic.**

RHOMBOHEDRON. A **prism** with six sides, all of which are parallelograms

RHUMBETRON. Another name for cavity resonator. (See **resonator, cavity.**)

RIBBON MICROPHONE. See **microphone, ribbon.**

RICCATI EQUATION. A first-order **differential equation** of the form

$$y' = A_0(x) + A_1(x)y + A_2(x)y^2.$$

It is the most general form of the first-order differential equation $y' = f(x,y)$, where $f(x,y)$ is **rational** in y and with a general solution containing no **singularities** except **poles.** Every second-order linear differential equation may be transformed into a **Riccati equation.**

RICHARDSON - DUSHMAN EQUATION. The basic equation of **thermionic emission.** Richardson first developed the equation from the thermodynamic theory of gases, while a later derivation by Dushman based on quantum mechanics gives identical results. This equation gives the thermionic current density, j, resulting from the emission of electrons from a metallic surface at the temperature T.

$$j = AT^2e^{-\phi/kT}$$

where A is a constant depending on the state of the surface, and ϕ is the **electronic work function** for the metal. Another form of this equation is:

$$I_s = AT^2e^{-E_W/E_T}$$

where I_s is the thermionic current density (ampere/meter^2); A is a constant having the dimensions ampere/(meter)^2 $\times$ (°K)^2; T is the temperature in °K; e is the natural logarithmic base; E_W is the **electronic work function** for the metal in electron-volts; and $E_T = T/11{,}600$, and is called the electron-volt equivalent of temperature.

RICHARDSON EQUATION. See **Richardson-Dushman equation.**

RICHARDSON NUMBER. A non-dimensional parameter appearing in the theory of the stability of shear flow in the presence of density stratification. It is

$$R_i = -\frac{g}{\rho}\frac{\partial\rho}{\partial Z}\Big/\left(\frac{\partial U}{\partial Z}\right)^2$$

where g is the acceleration due to gravity, ρ is the fluid density, Z is vertical displacement, U is velocity in the horizontal direction. If the fluid is effectively inviscid, it will become unstable at a critical value of the Richardson number

RICHARDSON PLOT. By plotting the logarithm of the thermionic current per squared Kelvin degree, i.e., log I/T^2, against the reciprocal of the absolute temperature, a straight line is obtained whose slope is a measure of the **activation energy** involved (see **Richardson-Dushman equation**). A similar plot is useful in any process involving thermal activation with a **Boltzmann factor.**

RID. Abbreviation for Radio Intelligence Division (of the Federal Communications Commission).

RIEKE DIAGRAM. A polar-coordinate **load diagram** for microwave **oscillators,** particularly **klystrons** and **magnetrons.** Constant-power and constant-frequency contours are plotted against the polar plot of **load admittance,** commonly called the **Smith chart.**

RIEMANN-CHRISTOFFEL TENSOR. The twenty independent quantities

$$B_{\mu\nu\sigma}{}^{\epsilon} = \Gamma_{\mu\sigma}{}^{\alpha}\Gamma_{\alpha\nu}{}^{\epsilon} - \Gamma_{\mu\nu}{}^{\alpha}\Gamma_{\alpha\sigma}{}^{\epsilon} + \frac{\partial}{\partial x^{\nu}}\Gamma_{\mu\sigma}{}^{\epsilon} - \frac{\partial}{\partial x^{\sigma}}\Gamma_{\mu\nu}{}^{\epsilon}$$

where $\Gamma_{\mu\sigma}{}^{\alpha}$ are the **Christoffel three-index symbols.** The vanishing of this tensor is a necessary condition for the space to which it applies (and in particular **space-time**) to be flat.

RIEMANN - CHRISTOFFEL TENSOR, CONTRACTED. See **contracted Riemann-Christoffel tensor.**

RIEMANN - PAPPERITZ EQUATION. A second-order linear **differential equation** of **Fuchsian type** with three regular **singular points** in the finite plane at $x = a, b, c$. It may be symbolized by the Riemann P-function

$$y = P\begin{Bmatrix} a & b & c & \\ a' & b' & c'; & x \\ a'' & b'' & c'' & \end{Bmatrix}$$

where a', a'', b', b'', c', c'' are the **exponents** at the singularities, y is the dependent variable and x, the independent variable. A special case of this equation is that known as the **Gauss hypergeometric equation.**

RIEMANN SURFACE. A surface used in representing **multivalued functions** of the **complex variable.** One sheet is assigned to each **branch** of the function, each sheet is cut at the branch line, and all are joined together so that a closed contour may be traced by passing continuously along the sheets of the surface.

RIEMANN ZETA FUNCTION. An infinite **series** in the **complex variable** $z = x + iy$, with n an integer

$$\zeta(z) = \sum_{n=1}^{\infty} n^{-z}.$$

The function is **meromorphic,** with a simple **pole** at $z = 1$.

RIEMANNIAN SPACE. Space in which the magnitude ds of the distance between two points with coordinates x^{μ}, $x^{\mu} + dx^{\mu}$, is defined as a homogeneous quadratic function of dx^{μ}, thus:

$$ds^2 = \sum_{\mu,\nu} g_{\mu\nu}dx^{\mu}dx^{\nu}$$

where $g_{\mu\nu}$ is the metric of the space.

RIGHI EXPERIMENT. Because of the non-coherence of light from different sources, it is difficult to produce "beats" with light such as are produced between sounds from two sources which emit with slightly different frequencies. By use of a rotating **Nicol prism,** a **Fresnel bi-mirror,** a **quarter wave plate** and a fixed Nicol prism, Righi produced an effect similar to beats. However, other explanations are possible for his results.

RIGHI-LEDUC EFFECT. If heat is flowing through a strip of metal and the strip is placed in a magnetic field perpendicular to its plane, a temperature difference develops across the strip. This effect, discovered in 1887 independently by Righi and by Leduc, bears the same relation to the **Nernst effect** that the **Ettingshausen effect** bears to the **Hall effect.** It may indeed be regarded as analogous to the Hall effect, but with a longitudinal flow of heat replacing the electric current and a transverse temperature difference replacing the potential difference. If, to one looking along the strip in the direction of the heat flow, and with the magnetic field downward, the decrease of temperature is toward the right, the effect is said to be positive. It is positive in iron and negative in bismuth.

RIGHT-HAND RULE (FOR GENERATOR ACTION). An observer having the velocity **v** in a magnetic field **B** "sees" an electric field given by $\mathbf{E} = \mathbf{v} \times \mathbf{B}$. A conductor moving across a magnetic field thus experiences an electric field which exerts force on the free charges in the conductor, inducing an emf. The rule for the sense of a vector cross-product leads to a mnemonic device using the thumb (T), the forefinger (F), and the center finger (C) spread to form convenient rectangular axes. By letting T represent thrust, or motion; F, the flux; and C, the current; a person's right-hand yields the correct sense for the induced current. Conversely, pointing C with the current and F with the flux, using the left hand, gives the resulting thrust in the direction T. This converse case is the *left-hand rule for motor action.*

RIGHT-HANDED (CLOCKWISE) POLARIZED WAVE. See **wave, right-handed (clockwise) polarized.**

RIGID BODY. An aggregate of material **particles** in which the interaction forces of the particles are such that the distance between any two particles remains constant with time.

RIGID BODY, GENERAL EQUATION OF MOTION. The motion of a rigid body can be described by the translational motion of the center of mass and the rotational motion about the center of mass. The equation for translational motion has the general form

$$\mathbf{F} = M\frac{d^2\mathbf{r}}{dt^2}.$$

F is the vector sum of all the forces acting on the rigid body, M is the total mass, and **r** is the position vector of the center of mass. The equation for rotational motion has the general form

$$\mathbf{L} = \frac{d\mathbf{H}}{dt}.$$

L is the resultant **torque** and **H** the vector **angular momentum** about the center of mass as an origin.

RIGID BODY, GENERAL EQUATION OF ROTATIONAL MOTION. For rotation about a particular origin, the general equation of motion is

$$\frac{d\mathbf{H}}{dt} = \mathbf{L}$$

where
$$\begin{aligned}\mathbf{H} = {} & \mathbf{i}(\omega_x I_{xx} - \omega_y I_{xy} - \omega_z I_{xz}) \\ & + \mathbf{j}(-\omega_x I_{yx} + \omega_y I_{yy} - \omega_z I_{yz}) \\ & + \mathbf{k}(-\omega_x I_{zx} - \omega_y I_{zy} + \omega_z I_{zz}).\end{aligned}$$

where **H** is the resultant angular momentum about the origin, **L** is the resultant torque about origin; the I-terms are moments and products of inertia (See **inertia, moments and products of.**)

RIGID BODY, KINETIC ENERGY OF. (1) The total kinetic energy of a rigid body undergoing general translation and rotation can be written as the sum of kinetic energy of translation of the center of mass and the kinetic energy relative to center of mass

$$T = \tfrac{1}{2}M\bar{v}^2 + \tfrac{1}{2}\sum_{i=1}^{n} m_i v_i^2$$

where $M = \Sigma m_i$ is the total mass, $\bar{v}^2$ is the square of velocity of center of mass, m_i is the mass of ith element, v_i is the velocity of ith element with respect to center of mass.

(2) Rigid body constrained at a fixed point. At any instant there will exist an instantaneous axis of rotation passing through the fixed point. The kinetic energy of rotation with respect to the fixed point can be written

$$T = \tfrac{1}{2}\boldsymbol{\omega}\cdot\mathbf{H}$$

where $\boldsymbol{\omega}$ is the instantaneous angular velocity vector; **H** is the instantaneous angular momentum vector.

Expanded, with moments of inertia referred to principal axes, the kinetic energy becomes

$$T = \tfrac{1}{2}(I_{xx}\omega_x^2 + I_{yy}\omega_y^2 + I_{zz}\omega_z^2)$$

where I_{xx}, I_{yy}, I_{zz} are moments of inertia (see **principal axes; moment of inertia**).

(3) Rigid body constrained to rotate about a fixed axis. When the rigid body rotates about a fixed axis, the kinetic energy is written

$$T = \tfrac{1}{2}I\omega^2$$

where I is the moment of inertia about fixed axis, ω is the angular velocity about fixed axis.

RIGID BODY, MOTION ABOUT A FIXED AXIS. When the motion is restricted to a fixed axis, the general equation of motion of a rigid body reduces to

$$\frac{d}{dt}(I\omega) = L$$

where I is the moment of inertia about the fixed axis, ω is the angular velocity about the fixed axis, L is the resultant torque about the fixed axis. (See **rigid body, general equation of motion.**)

RIGID BODY, MOTION ABOUT A POINT. The fundamental equation of motion for rotational motion of a rigid body about a fixed point is

$$\frac{d\mathbf{H}}{dt} = \mathbf{L}$$

where $\frac{d\mathbf{H}}{dt}$ is the time derivative of total vector angular momentum about the point, **L** is the resultant torque about the point.

If the moments of inertia are referred to the principal axes, with origin at fixed point and axes fixed in the body, this equation becomes

$$\mathbf{L} = \mathbf{i}[I_{xx}\dot{\omega}_x + (I_{zz} - I_{yy})\omega_y\omega_z] + \mathbf{j}[I_{yy}\dot{\omega}_y + (I_{xx} - I_{zz})\omega_z\omega_x] + \mathbf{k}[I_{zz}\dot{\omega}_z + (I_{yy} - I_{xx})\omega_x\omega_y].$$

(This is also known as the **Euler equation** for a rigid body) (See also **rigid body, general equation of motion.**)

RIGID CYLINDER, MOTION ON AN INCLINED PLANE. A rigid cylinder or cylindrical shell rolling on an inclined plane without slipping undergoes both translation and rotation. The equation of motion can be written

$$\ddot{x} = \frac{W \sin \theta}{\frac{W}{g} + I/a^2},$$

where W is the weight of cylinder, g is the acceleration of gravity, θ is the angle of inclination of plane, I is the moment of inertia of cylinder about axis, a is the radius of the cylinder, x is the acceleration along plane.

For any other object of spherical or circular symmetry the appropriate moment of inertia is substituted for I. (See **rigid body, motion about an axis.**)

RIGIDITY, MODULUS OF. The **elastic modulus** corresponding to a shear stress on a pair of orthogonal planes.

RING. (1) A toroidal core. (2) The ring-shaped contact between the sleeve and tip on a **phone plug.**

RING CIRCUIT. The name sometimes applied to a **bridge modulator** or **rectifier.**

RING COUNTER. A series of **bistable multivibrators** or **trigger circuits,** connected in tandem to form a sequence-operated type of **counting circuit.**

RING MODULATOR. A **rectifier modulator (demodulator)** employing four diode elements connected in series to form a ring. The diodes are connected with a polarity which will readily permit current flow around the ring in one direction. Appropriate input and output connections are made to the four nodal points of the ring. The ring modulator is also called the double-balanced modulator. It can serve as a **balanced modulator** as well as a phase-sensitive detector or demodulator.

RING SCALER. A **scaling circuit** in which the asymmetrical condition is passed along to the next tube in line, with the last tube feeding back to the first.

RINGING. An oscillatory **transient** occurring in the output of a system, as a result of a sudden change in input.

RIPPLE(S). (1) Surface waves on a liquid whose wavelength is so short that the motion is effectively controlled by **surface tension** forces. This requires that the wavelength should be less than

$$\lambda_c = 2\pi \sqrt{\frac{\gamma}{\rho g}}$$

where γ is surface tension, and ρ, liquid density. For water, λ_c = 1 7 cm.

(2) The a-c component from a d-c power supply, arising from sources within the power supply. Unless otherwise specified, per cent ripple is the ratio of the root-mean-square value of the ripple voltage to the absolute value of the total voltage, expressed in per cent.

RIPPLE, PER CENT. The ratio of the effective (root-mean-square) value of the **ripple voltage** to the average value of the total voltage, expressed in per cent

RIPPLE VOLTAGE. The alternating component of the unidirectional voltage from a **rectifier** or **generator** used as a source of direct-current power.

RIPPLED-WALL AMPLIFIER. See **amplifier, rippled-wall.**

RISE TIME. See **time constant**

RISING-SUN MAGNETRON See **magnetron, rising-sun.**

RISLEY PRISM. See **prism, Risley.**

RITCHIE WEDGE. A **photometer** in which the standard source and the test source of light illuminate two white, diffusing surfaces, 90° apart and intersecting in a movable wedge; so arranged that they are viewed from a direction perpendicular to the line joining the sources.

RITZ COMBINATION PRINCIPLE. See **combination principle.**

RMA. Abbreviation for the Radio Manufacturers Association, which has now been supplemented by the Radio-Electronics-Television Manufacturers' Association.

RMS. Abbreviation for **root-mean-square.**

RMS (EFFECTIVE) PULSE AMPLITUDE. See **pulse amplitude, RMS (effective).**

ROBIN LAW. When a system is in a condition of either chemical or physical **equilibrium,** an increase of pressure favors the system formed with a decrease in volume; a reduction in pressure favors the system formed with an increase in volume; and a change of pressure has no effect upon a system formed without a change in volume. (Cf. **Le Chatelier Principle.**)

ROCHON PRISM. See **prism, Rochon.**

ROCKY POINT EFFECT. See **flash arc.**

RODRIGUES FORMULA. See **Legendre polynomial.**

RODS. A part of the **retina** of the eye primarily responsive to light but not to color. Absence of or reduced number of rods is connected with inability to see well with low level of illumination. (See **cones, night blindness.**)

ROENTGEN. The quantity of x- or γ-radiation such that the associated corpuscular emission per 0.001293 gram of air produces, in air, ions carrying 1 electrostatic unit of quantity of electricity of either sign.

ROENTGEN EQUIVALENT, MAN (REM) (A PROPOSED UNIT; PARKER). The dose of any ionizing radiation that will produce the same biological effect as that produced by one **roentgen** of high voltage x-radiation.

ROENTGEN EQUIVALENT PHYSICAL (REP) (A PROPOSED UNIT; PARKER). A unit proposed to apply to statements of dose of ionizing radiation not covered by the definition of the **roentgen.** It has been variously defined as the dose which produces energy absorption of 83 ergs per gram of tissue or 93 ergs per gram of tissue. The actual energy absorption in tissue per roentgen is a function of the tissue composition and of the wavelength of the radiation, and ranges between 60 and 100 ergs per gram.

Various authors have used the term roentgen equivalent or equivalent roentgen, basing the equivalence on energy absorption by **air,** or on the number of ion pairs produced in air by one roentgen of **x-rays,** or on the energy absorption in tissue from one roentgen of x-rays, or on the ionization produced in a small air cavity by one roentgen of **x-rays.** The magnitude of all these units is the same within about 10 per cent, in terms of energy absorbed per gram of tissue.

ROENTGEN RAYS. See **x-rays.**

ROLL OUT (VERB). To read out of a storage device by simultaneously increasing by one the value of the digit in each column and repeating this r times (where r is the **radix**) and, at the instant the representation changes from $(r - 1)$ to zero: (a) generating a particular signal, or (b) terminating a sequence of signals, or (c) originating a sequence of signals.

ROLLE THEOREM. Let $f(x)$ be a function which vanishes at $x = a$ and at $x = b$, and which has a finite derivative $f'(x)$ at all points in the interval (a,b). Then $f'(x)$ vanishes at some point x_0 between a and b.

ROLLING RESISTANCE (OR FRICTION). In the rolling of a wheel on a plane surface there is some distortion of the two surfaces in contact due to the normal force between the surfaces. Such distortion smears out the ideal line contact and effectively introduces a force with a component in opposition to the motion. This component of force is called the rolling resistance or friction F_r and is proportional to the normal force N. A coefficient of rolling resistance or friction u_r can be defined by $u_r = F_r/N$, where F_r can be determined experimentally by observing the deceleration on a horizontal surface.

RÖMER METHOD (VELOCITY OF LIGHT). Römer, in 1676, first obtained an approximate value for the velocity of light by observing the apparent changes in the periods of the moons of Jupiter as the distance between the earth and Jupiter changed during a year.

RONCHI TEST. An improved method over the **Foucault knife-edge test** for testing curved mirrors is to replace the knife-edge with a transmission **grating,** having 40–200 lines to the inch, and to replace the pinhole

source with a slit or a section of the same grating.

ROOF PRISM. See **prism, roof.**

ROOM, DEAD. A room which is characterized by an unusually large amount of sound absorption.

ROOM, LIVE. A room which is characterized by an unusually small amount of sound absorption.

ROOT. If a is a real number, n an integer, then x is the nth **root** if the product of x taken n times equals a. The number of nth roots is n but not all of them need be real. They are given for any number, real or complex, by the **DeMoivre theorem.** (See also **radical** and **polynomial equation.**)

ROOT-MEAN-SQUARE SOUND PRESSURE. See **sound pressure, effective.**

ROOT-MEAN-SQUARE QUANTITY. The square root of the time average of the square of the quantity, e.g., velocity of a particle. If the quantity takes on only n discrete values x_j, the root-mean-square value is

$$x_{rms} = \{(1/n) \sum_{j\ 1} x_j^2\}^{1/2}.$$

If on the other hand, the quantity is a function, say of time t, defined by $x(t)$,

$$x_{rms} = \{(1/T) \int_0^T x^2(t)dt\}^{1/2}.$$

In the latter case, the integral is extended over the time for which the rms value is desired or, if the function is periodic, over any integral number of periods.

ROOTER. A device which takes the nth root of the instantaneous amplitude of a **video signal.** Its function is to linearize the **overall transfer characteristic,** and thus improve the picture quality in a television system.

ROSA AND DORSEY METHOD (VELOCITY OF LIGHT). The ratio between electrical quantities expressed in electrostatic units and in absolute electromagnetic units is always some simple power of the velocity of light. The capacitance of an electrical condenser may be measured experimentally in **abfarads,** and computed from the geometrical dimensions and configuration in **statfarads.** One abfarad equals (velocity of light)^2 statfarads. By making these measurements, Rosa and Dorsey of the National Bureau of Standards obtained a value for the velocity of light in quite good agreement with the more direct measurements.

ROSENBERG CROSS-FIELD GENERATOR. One form of electrodynamic amplifier. (See **amplifier, electrodynamic.**)

ROTAMETER. An instrument which measures the flow of gases and liquids by the position of a float in a slightly-conical, vertical tube inserted in the flow system. By arranging that the flow rotates the float, sticking of the float to the walls of the tube can be avoided.

ROTARY JOINT. A **joint** connecting an immobile section of a **waveguide** or **coaxial line** to a section which must be free to turn. Since reliable, current-conducting sliding-contacts are difficult to maintain, one or more half-wavelength short-circuited lines are usually incorporated in the joint in such a manner that the actual point of sliding contact is at or near a current minimum.

ROTATE (LIGHT). To turn the plane of **polarized light** either to the right or left.

ROTATING CRYSTAL METHOD. A technique for the **x-ray analysis of crystal structure,** in which a beam of x-rays impinges on a crystal which is rotated about one of its **crystallographic axes,** at right angles to the beam. As various planes come successively into position, the reflected beams are received as spots on a photographic plate.

ROTATING CYLINDER METHOD FOR VISCOSITY. A cylinder is suspended on a torsion fiber coaxially inside another cylinder which can be rotated at constant speed. The space between cylinders is filled with the fluid under investigation, and its viscosity is determined by the drag suffered by the inner cylinder.

ROTATING JOINT. A **coupling** for transmission of electromagnetic energy between two **waveguide** structures designed to permit mechanical rotation of one structure.

ROTATION. Motion of a rigid body in which one or two points of the rigid body are kept fixed.

ROTATION AXIS. A **symmetry element** possessed by certain crystals, whereby the crystal can be brought into a physically equivalent position by rotation about an axis which can be one-fold, two-fold, three-fold, four-fold or six-fold, according to whether the crystal can be brought into self-coincidence by the operations of rotation through 360°, 180°, 120°, 90°, or 60° about the rotation axis.

ROTATION, DYNAMICS OF. A body is said to rotate when all of its particles move in circles about a common axis with a common **angular velocity.** This motion may be either free or constrained, as illustrated, respectively, by the earth turning on its axis, and by a flywheel or a pendulum.

If one twirls an umbrella about its handle, it tends to open. This is because the **centrifugal forces** exert torques tending to throw the stays outward on their pivots. Through any point of a rigid body there are at least three lines, mutually perpendicular, about which the body would rotate without any such centrifugal torque. It may be shown that the **moment of inertia** of the body with respect to any one of these lines is either a maximum or a minimum as regards all lines through the given point. They are called **principal axes.** In general there is only one line about which a free body will rotate permanently; it is the principal axis of greatest moment of inertia through the **center of mass.** A body constrained to rotate about an arbitrary axis will, when released, tend to change its motion so as to rotate about this permanent axis, but the adjustment is complicated by **precession,** so that the body may "wobble" like a badly thrown discus.

The most general case of rotation is that of a rigid body about a single fixed point, as in a top or **gyroscope.** If a free body, at rest, is given a sudden push along some line not through the center of mass, it begins to rotate about some other line beyond the center of mass and perpendicular to the applied force. This line is the axis of instantaneous rotation. It is only a temporary axis, the rotation being at once transferred to an axis through the center of mass. The line mutually perpendicular to the instantaneous axis and to the line of the force passes through the center of mass, and its intersections with the other two lines are conjugate points, having the same relation as the center of oscillation and the center of suspension of a rigid **pendulum.** If the push is given in line with the center of mass, the axis of instantaneous rotation is at infinity, and the motion is then one of pure translation.

A torque applied so as to tend to change the axis about which a body is rotating results in the peculiar behavior known as **precession.** The **angular momentum** of a rotating body is the product of its angular velocity by its moment of inertia about the axis of rotation. The **kinetic energy** associated with rotational motion is equal, in absolute units, to ½ the product of the moment of inertia by the square of the angular velocity—a formula analogous to that for kinetic energy of linear motion.

ROTATION-INVERSION AXIS. A **symmetry element** possessed by certain crystals by which the crystal is brought into self-coincidence by a combined rotation about the axis and **inversion.**

ROTATION, MOLAR. Or molar rotatory power or molecular rotation. The product of the specific rotation by the molecular weight, divided by 100. The form of this relationship is

$$[M] = M[\alpha]/100$$

in which $[M]$ is the molar rotation, M is the molecular weight, and $[\alpha]$ is the specific rotation. The direct form of this relationship is

$$[M] = M\alpha/100l\rho$$

in which $[M]$ is the molar rotation, M is the molecular weight, α is the angle of rotation for a column of liquid of effective length, l, and ρ is the density of the liquid. (See **rotation, specific.**)

ROTATION, MOLECULAR. In the solid state, certain compounds show anomalies of **specific heat, crystal symmetry** and **dielectric constant** around a definite temperature. This has been interpreted as showing the onset of rotation of the molecules or complex ions in the **lattice,** as if they were more or less freely pivoted at their proper lattice sites. The exact conditions for this effect to occur before the crystal melts are complicated, but the phenomenon is fairly common, especially in diatomic molecules of the type of H_2, HCl, etc.

ROTATION OF PLANE OF POLARIZATION OR LIGHT IN MAGNETIC FIELD. See **Faraday effect.**

ROTATION OF THE VIBRATION PLANE. Certain substances, i.e., crystalline quartz along the optic axis, certain liquids (turpentine) and solutions (sugar or tartaric acid), and certain isotropic substances when placed in a strong magnetic field have the ability to rotate the plane of polarization of polarized light passing through them. (See Robertson, *Introduction to Optics*, 4th Ed.)

ROTATION PHOTOGRAPH. A photograph of the **diffraction pattern** obtained by rotation of a single crystal in the beam of impinging x-rays.

ROTATION-REFLECTION AXIS. A **symmetry element** possessed by certain crystals, whereby the crystal is brought into self-coincidence by combined rotation and reflection in a plane perpendicular to the axis of rotation. Rotation-reflection axes may be one-fold, two-fold, three-fold, four-fold, or six-fold, according to whether the rotation which, with the reflection, brings the crystal into self-coincidence, is through an angle of 360°, 180°, 120°, 90° or 60°.

ROTATION, SPECIFIC. The angular rotation of the plane of polarization as it passes through an optically-active material, divided by the length of the path and the density of the material. Sugar solutions are ordinarily measured for 10 cm path-length The 10 cm specific rotation of sugar (sucrose) solution is 66.67°.

ROTATIONAL CONSTANT. The constant B, appearing in the rotational term of molecular spectra, and defined by the expression

$$B = \frac{h}{8\pi^2 cI}$$

where h is the Planck constant, c is the velocity of light, and I is the moment of inertia of the molecular system about the axis of rotation. Besides being a factor, B is the reciprocal moment of inertia.

The **Schrödinger equation** for a symmetrical rotating molecule, referred to the spherical polar coordinates r, θ, ϕ is

$$\frac{1}{\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial\psi}{\partial\theta}\right) + \frac{8\pi^2 IE\psi}{h^2} = 0,$$

where E is the energy of rotation and I is the moment of inertia. Substitution of $x = \cos\theta$ reduces the equation to a **Legendre equation,** hence the **eigenfunctions** are the **spherical harmonics** $\psi = P_l(x)$ and the eigenvalues of E are

$$E_l = \frac{l(l+1)h^2}{8\pi^2 I} = Bcl(l+1).$$

ROTATIONAL ENERGY OF DIATOMIC MOLECULES. In the *Report on Notation for Spectra of Diatomic Molecules*, Mullikan, *Phys. Rev.* **36**, 623 (1930), the rotational energy E_r is defined as the difference between the energy of the actual molecule and that of an idealized molecule obtained by the following imaginary process: the rotation of the nuclei is gradually stopped without placing any new constraint on the vibration of the nuclei or on the electron motions, in such a way as might be realized by gradually (i e., adiabatically) coupling an infinite moment of inertia to the axis of rotation of the molecule (See **adiabatic approximation; rotational constant.**)

ROTATIONAL FLOW. See **flow, rotational.**

ROTATIONAL PARTITION FUNCTIONS. See **partition function.**

ROTATIONAL SUM RULE. In symmetric top molecules if the line strengths of the three transitions with the same J'' are added for a given electronic transition, apart from a constant factor, the value $2J'' + 1$ (or $2J' + 1$ for transitions with the same J') is obtained; that is, a (rotational) sum rule holds: the sums of all the line strengths from or to a given rotational level are proportional to the statistical weight of that level.

ROTATIONAL WAVE. See **wave, shear.**

ROTATOR. In **waveguides,** a means of rotating the plane of polarization. This may be done very simply in the case of a rectangular guide by twisting the guide itself.

ROTATORY. Optically active. Capable of rotating the plane of polarized light, distinguished as dextro-rotatory and levo-rotatory.

ROTATORY POWER, OPTICAL. The ability of a substance to rotate the plane of polarization of **polarized light.**

ROTOTRAL. A form of electrodynamic amplifier (see **amplifier, electrodynamic**) often used in **feedback** control systems, which generally consists of two cascaded, simple separately-excited generators driven at constant speed. The first generator-stage commonly has two equal field-coils connected in opposition, one of which is excited by a reference current, the other by a current proportional to the output of the controlled device.

ROTOR. The rotating portion of a **dynamo** or of any other machine, such as a **centrifuge.** (See also **generator, electrical.**)

ROUND-OFF (VERB). In computer terminology, to delete less significant digits from a number, and possibly apply some rule of correction to the part retained.

ROUND WINDOW. An opening from the cavity of the inner ear to the middle ear. It is covered by an elastic membrane and is sometimes called the secondary eardrum.

ROUTINE. A sequence of operations which a **digital computer** may perform, or the sequence of instructions which determine these operations.

ROW LINES. Lines formed by the diffraction spots on a rotation photograph of a crystal as obtained by rotation of a crystal in a beam of x-rays, and photographing the **diffraction pattern.**

ROWLAND CIRCLE. The **slit, grating** and primary **astigmatic focus** of a concave **diffraction grating** all lie on a circle known as the Rowland circle.

ROWLAND GHOSTS. Discussed under **ghosts.**

ROWLAND MOUNTING. A method of mounting a **diffraction grating** and plate holder at the ends of a rigid bar each of which rides on separate straight tracks which intercept each other at right angles. The slit is placed at the intersection of the two tracks.

RUBICON MICROVOLT POTENTIOMETER. See **potentiometer, Rubicon microvolt.**

RUBIDIUM. Metallic element. Symbol Rb. Atomic number 37.

RULING-ENGINE. A mechanism operated by a long **micrometer** screw for ruling the equally spaced line on optical **gratings.** The first, good ruling-engine was made by H. A. Rowland (1882).

RUMBLE, TURNTABLE. See **turntable rumble.**

RUNDOWN. The linear fall of plate voltage in a Miller sweep generator.

RUNGE-KUTTA METHOD. A numerical method for solving a **differential equation.** Let the given equation be $y' = f(x,y)$ with initial values (x_0,y_0). Four quantities are calculated

$$k_1 = f(x_0,y_0)h$$
$$k_2 = f(x_0 + h/2,\ y_0 + k_1/2)h$$
$$k_3 = f(x_0 + h/2,\ y_0 + k_2/2)h$$
$$k_4 = f(x_0 + h,\ y_0 + k_3)h.$$

Then

$$x_1 = x_0 + h$$
$$y_1 = y_0 + \Delta y$$
$$\Delta y = 1/6(k_1 + 2k_2 + 2k_3 + k_4)$$

The method may be generalized for simultaneous first-order differential equations.

RUPTURE, MODULUS OF. A measure of the ultimate strength or the breaking load per unit area of a specimen as determined from a torsion, or more commonly from a bending test. The modulus is calculated from the breaking load assuming that the specimen remains elastic until rupture occurs, although this may not be the case. Its value will be intermediate between the ultimate tensile and compressive strengths.

RUSSELL EFFECT. This effect is also known as the Vogel-Colson-Russell effect as it was independently observed in different forms by all three. It is the general term applied to the formation of latent developable images on photographic films and papers by agents other than radiant energy and specifically by resins, metals, printing inks, volatile liquids, gaseous fumes, etc. In many cases the effect appears to be due to the release of hydrogen peroxide which is capable of rendering the silver halides developable without exposure to light.

RUSSELL-SAUNDERS COUPLING. See **coupling, Russell-Saunders.**

RUTHENIUM. Metallic element. Symbol Ru. Atomic number 44.

RUTHERFORD. (1) A unit of **radioactivity,** symbol rd, equal to 10^6 disintegrations per sec. (2) A quantity of a nuclide having an **activity** of 1 rutherford.

RUTHERFORD SCATTERING. See **scattering, Rutherford.**

RYDBERG CONSTANT. A quantity which enters into the frequency or wave number formulae for all **atomic spectra.** It has nearly the same value for all elements, and has only to be multiplied by a factor dependent in a regular way upon the ordinal number of the line to give the wave number of each line in a given hydrogen-like spectral series. Bohr derived the following expression for the constant in the case of any atom, the mass of whose nucleus is M:

$$R = \frac{2\pi^2 me^4}{ch^3(1 + m/M)};$$

in which m is the mass and e the charge of the electron, c is the **electromagnetic constant** (speed of light), and h is the Planck constant Since m/M is in any case very small, it is clear that R cannot vary much from element to element. Its smallest value (for hydrogen) is about 109,677.591 reciprocal cm, and it can never exceed 109,737.323 reciprocal cm. If R is multiplied by c, the result is the "Rydberg fundamental frequency" (called by some writers the Rydberg constant); and if this be used in place of R, the spectral series formulae give frequencies instead of wave numbers.

RYDBERG CORRECTION. In the motion of an electron about a core which is not a point charge, the orbits (in the Bohr theory) were considered not to be simple ellipses, but ellipses whose orbits rotate uniformly (rosette motion). In this case, the energy is not independent of the azimuthal quantum number l, and is given by the formula:

$$E_{n,l} = \frac{R'Z^2}{(n + a)^2}$$

where $E_{n,l}$ is the energy, $R' = hcR$, where h is the Planck constant, c the velocity of light, and R is the Rydberg number Z is the charge on the core (the atomic number less the core electrons), n is the principal quantum number, and a is the Rydberg correction, which depends on the azimuthal quantum number, and approaches zero with increasing l.

S

S. (1) Second (s) (2) Scattering coefficient (turbidity) (s). (3) Solubility (s or S). (4) Specific surface (s). (5) Area (S). (6) Acoustic condensation (s). (7) Exponential compressibility (s). (8) Cross section (s). (9) Elastance, or reciprocal capacitance (S). (10) Action (S). (11) Displacement (s), linear displacement (s). (12) Total entropy (S), entropy per atom or molecule (s or s_m), entropy per unit mass (s), entropy per mole (s, S or S_M). (13) Length of path or arc (s). (14) Slip in electrical machinery (s). (15) Stopping power (S), mass stopping power (S_m), linear stopping power (S_l), atomic stopping power (S_a). (16) Optical object distance (s). (17) Optical image distance (s'). (18) Sensitivity of phototube (dynamic, s) (static, S). (19) Sulfur (S). (20) In spectroscopy, shaded or displaced to shorter waves (s). (21) Spin quantum number of electric spin of an electron quantized in units of $\hbar$ (s), resultant spin quantum number or resultant angular momentum spin of two or more electrons quantized in units of $\hbar$ (S). (22) Type of electron with azimuthal quantum number of 0 (s). (23) Spectral term symbol for L-value of 0 (S).

S METER. A meter used in some communication receivers to measure relative **signal strength.** This meter is sometimes placed in the plate circuit of an intermediate-frequency **amplifier** which is subject to **automatic gain control.** The plate current in this stage is thus an inverse function of signal strength.

S-STATE. A state of zero orbital angular momentum.

SABATIER EFFECT. This effect, studied by Sabatier, is a reversal phenomenon observed with photographic materials under certain conditions as when the developed image is exposed to diffuse light and redeveloped. Reversal of the image, under these conditions, is usually due to the first negative image acting as a stencil during the second exposure, the positive image being formed by the exposure of the undeveloped silver halide through the negative image.

Reversal of the image, however, may also be produced by the substitution of certain chemicals, such as sodium arsenite, for the exposure to diffuse light. Exposure to x-rays under these conditions does not result in reversal. Students are now agreed that the Sabatier effect is not a simple case of second exposure as described above but a different phenomenon connected apparently with the development of the images.

SABIN. A measure of the sound absorption of a surface. It is the equivalent of 1 square foot of a perfectly absorptive surface.

SABINE LAW. An experimental formula for the **reverberation time** in a room. It has the same form as the **Franklin equation.**

SACCHARIMETER. A **polarimeter** calibrated to read directly the purity of a sugar solution.

SACKUR-TETRODE EQUATION. An equation giving the translational **entropy** of an ideal gas. With certain simplifying approximations, it becomes:

$$S_{tr} = R\left[\ln \frac{(2\pi mkT)^{3/2}}{h^3N} V + \frac{5}{2}\right]$$

in which S_{tr} is the translational **entropy** of one mole of gas, R is the **gas constant,** m is the **molecular mass,** k is the **Boltzmann constant,** T is the absolute temperature, h is the Planck constant, N is the **Avogadro constant,** and V is the molecular volume.

SADDLE. See **col.**

SADDLE POINT. A point (x_0,y_0) on a surface $f(x,y)$ where $f(x,y_0)$ is a maximum at $x = x_0$ and $f(x_0,y)$ at the same time is a minimum at $y = y_0$. A familiar example is the **hyperbolic paraboloid,** which has a **saddle point** at the origin if its standard equation is taken as $x^2/a^2 - y^2/b^2 = 2cz$. A person walking toward the origin in the XZ-plane

would be ascending a mountain peak while he would be descending into a valley if he walked in the YZ-plane. (Also called a **minimax** or a col.)

SAGITTA. In elementary studies of the optics of curved surfaces, an approximate value for the sagitta to an arc of a circle is frequently useful. When $x \ll y$ the exact equation, $r^2 = (r - x)^2 + y^2$ reduces to $x \approx y^2/2r$, where $OA = r$ is the radius, $AC = 2y$ is the chord and $DB = x$ is the sagitta.

SAGITTAL FOCUS. See **astigmatic focus.**

SAINT ELMO FIRE. A brush-like discharge from charged objects in the atmosphere. It occurs on ship masts, on aircraft propellers, wings and other projecting parts, and, in general, on objects projecting from high terrain.

SAKATA-TAKETANI EQUATION. Relativistic equation for a particle of spin zero which has an appearance similar to that of the non-relativistic **Schrödinger equation.**

SALT BRIDGE. A type of liquid junction used to connect electrically two electrolytic solutions. It consists commonly of a U-tube filled with a strong salt solution, and provided with porous plugs. It is used for such purposes as to connect electrolytic **half cells** in making measurements of **electrode potential.**

SAMARIUM. Rare earth metallic element. Symbol Sm. Atomic number 62

SAMPLE POINT. The point on a **chromaticity diagram** that represents the **chromaticity** of the sample.

SAMPLING ACTION. In an **automatic controller,** that action in which the difference between the independent variable and the controlled variable is measured and correction made only at intermittent intervals.

SAMPLING PRINCIPLE. The specification of the least number of discrete values (samples) of an unknown function necessary for its complete and unambiguous definition.

SANAPHANT. A circuit with characteristics intermediate between the **phantastron** and the **sanatron.**

SANATRON. A form of the **phantastron** in which the gating waveform is generated in a second tube.

SANDWICH PHOTOCELL. Colloquialism for a **photovoltaic cell.**

SARGENT CURVES. Graphs obtained by plotting the logarithms of the radioactive **disintegration constants** of β-emitting radioelements, against the corresponding logarithms of their maximum β-particle energies. Most of the points corresponding to the natural radioelements were found to fall on two straight lines.

An interpretation of this result was provided by the **Fermi theory** of **β-decay** based upon the **neutrino concept,** which yielded the relationship between the disintegration constant and the maximum β-particle energy, which in its logarithmic form is

$$\log \lambda = \log k + 5 \log E_{max}.$$

SARGENT CYCLE. A quantity of ideal gas is taken through the following reversible processes: (a) From pressure P_1 and temperature θ_1 compressed adiabatically to temperature θ_2. (b) Heated at constant volume from temperature θ_2 to temperature θ_3. (c) Expanded adiabatically from temperature θ_3 to pressure P_1 and temperature θ_4. (d) Cooled at constant pressure P_1 to temperature θ_1. The efficiency of such an engine is

$$1 - \gamma \frac{\theta_4 - \theta_1}{\theta_3 - \theta_2}$$

where γ is the ratio of specific heats (C_p/C_v).

SATURABLE CORE, IDEAL. A core displaying idealized magnetic characteristics, i.e., a **magnetization curve** represented by two straight lines, having μ = zero above the knee and μ = infinity below the knee, and having no losses and hence no hysteresis loop.

SATURABLE REACTOR. A saturable reactor (see **reactor (2)**) is an adjustable inductor in which the current versus voltage relationship is adjusted by control magnetomotive forces applied to the core.

SATURABLE REACTOR, HIGH CONTROL IMPEDANCE. See **magnetic amplifier.**

SATURABLE REACTOR, IDEAL. A **saturable reactor** employing ideal core or cores, having perfect coupling between power and control windings and characterized by absence of losses, winding resistance and capacitances.

SATURABLE REACTOR, LOW CONTROL IMPEDANCE. See **magnetic amplifier.**

SATURABLE TRANSFORMER. A **saturable reactor** in which both output windings and power windings are employed, commonly to secure voltage transformation or circuit isolation from the a-c supply.

SATURATED ACTIVITY (NUCLEAR REACTOR). The maximum **activity** obtainable by **activation** in a definite flux. The saturated activity is proportional to the magnitude of the flux. Saturation results when the rate of formation of the activity is essentially equal to its rate of decay, and is approached when the irradiation time is long compared to the **half life** of the activity.

SATURATING REACTOR. An **inductor (1)** operating in **saturation (5)** without independent control means.

SATURATION. The state of being satisfied, or replete, or the action of bringing about that state. Some specific uses of this term apply to a single substance, entity or region, and others to relations between more than one, as: (1) Saturation current is the **ionization current** which results when the applied potential is sufficient to collect all ions. It is the maximum current that will pass through a gas under definite conditions of ionization. It is a measure of the charge carried by the ions produced in each second, and hence may be used as a measure of the **radioactivity** of a substance. (2) Color saturation is the attribute of any color perception possessing a **hue,** that determines the degree of its difference from the **achromatic color** perception most resembling it. This is a subjective term corresponding to the psychophysical term **purity.** The description of saturation is not commonly undertaken beyond the use of rather vague terms, such as vivid, strong, and weak. The terms brilliant, pastel, pale and deep, which are sometimes used as descriptive of saturation, have connotations descriptive also of **brightness.** (3) The saturated activity of a nuclear **reactor** is the maximum activity obtainable by **activation** in a definite flux. (4) A saturated vapor is a vapor whose temperature corresponds to the boiling temperature at the pressure existing on it. Expressing the same thought another way, a vapor is saturated when its temperature is a function of its pressure alone. A saturated vapor may be wet or dry, and the term does not imply, necessarily, a wet vapor. A vapor of 100% quality, having no superheat, is said to be dry and saturated. (5) Magnetic saturation is the maximum **magnetization** (or the maximum permanent magnetization) of which a body or substance is capable. (6) As applied to a **solution,** saturation is the process or condition of dissolving in a **solvent** all of a **solute** which the solvent can absorb, under equilibrium conditions at a given temperature. (7) Saturation is the complete neutralization of an acid or base. (8) A saturated compound is an organic compound in which each carbon valency is combined with a distinct atom, except that double- or poly-linkages between carbon and certain other elements (particularly nitrogen) do not cause unsaturation.

SATURATION ANGLE. Synonym for **gate angle.**

SATURATION INTERVAL. That portion of the supply cycle, expressed in per cent or degrees, during which the core of a saturable-core device is saturated, and the **gate winding** cannot absorb or support voltage.

SATURATION, MAGNETIC. Magnetic saturation is a term used generally to describe the condition of a magnetic material at high values of induction with small incremental permeability. (See **permeability, incremental.**)

SATURATION REACTANCE. The reactance of the **gate windings** of a magnetic amplifier during the **saturation interval.**

SATURATION SCALE. A series of visual stimuli perceived by an observer to have equal differences in saturation. (See **saturation (2).**)

SATURATION, TEMPERATURE. See **temperature saturation.**

SATURATION VOLTAGE. (1) The minimum value of applied potential required to produce saturation current (see **saturation (1)**). (2) The highest voltage which may be impressed on a **gate winding** without causing saturation for the condition of zero net d-c magnetomotive force.

SAVART PLATE. A device consisting of two calcite plates of equal thickness, cut parallel

to the natural cleavage faces and mounted with corresponding edges at right angles. Used to detect the presence of **polarized light** by means of **interference** fringes on a principle first described by Brewster.

SAWTOOTH WAVE. See **wave, sawtooth.**

SAYBOLT VISCOSIMETER. See **viscosity, measurement of.**

SCALAR. A quantity which has magnitude only, as distinguished from a **vector,** which has direction also. A true **scalar** has the same magnitude in all coordinate systems but see **pseudoscalar.**

SCALAR FIELD. A region of space described at each point by means of a **scalar function.** Examples, the atmosphere, in which the temperature may vary from one place to another; an unstirred solvent containing excess solute, where the concentration may vary before saturation is reached. Such a field is characterized by the fact that its numerical value at a point is the same in all coordinate systems. In **relativity** theory such coordinate systems are extended to include those obtained by a **Lorentz transformation.**

SCALAR POTENTIAL. Function of position and time $\phi(\mathbf{r},t)$ used to partly specify an electromagnetic field. In the case of an electrostatic field **E** the scalar potential becomes the electrostatic potential, with $\mathbf{E} = -\nabla\phi$. (See **vector potential.**)

SCALAR PRODUCT. If **A** and **B** are two **vectors,** of magnitude A, B, respectively, their **scalar product** is

$$\mathbf{A}\cdot\mathbf{B} = AB\cos\theta$$

where θ is the angle between the two vectors. This product, which is a scalar quantity, is also known as the dot or inner product. If the vectors are complex, the result of multiplication is the Hermitian scalar product (see **vector space**).

The scalar product of two vectors obeys the **commutative** and **distributive** laws:

$$\mathbf{A}\cdot\mathbf{B} = \mathbf{B}\cdot\mathbf{A};\quad \mathbf{A}\cdot(\mathbf{B}+\mathbf{C}) = (\mathbf{A}\cdot\mathbf{B}) + (\mathbf{A}\cdot\mathbf{C}).$$

If **A** is perpendicular to **B**, then $\mathbf{A}\cdot\mathbf{B} = 0$; and consequently, if $\mathbf{A}\cdot\mathbf{B} = 0$, then **A** is perpendicular to **B**. If **A** is parallel to **B**, then $\mathbf{A}\cdot\mathbf{B} = AB$. Consequently, $\mathbf{A}\cdot\mathbf{A} = A^2$ or the square of the length of **A**.

SCALE. (1) A balance used for weighing; (2) a series of markings at regular intervals which are used for measurement or computation. (3) A defined set of values in terms of which quantities of the same nature as those defined may be measured, e.g., **temperature scale.**

SCALE DIATONIC. See **scale, just.**

SCALE, EQUALLY TEMPERED. A series of notes selected from a division of the octave (usually) into 12 equal intervals.

EQUALLY TEMPERED INTERVALS

Name of Interval	Frequency Ratio	Cents
Unison	1:1	0
Minor second or semitone	1.059463:1	100
Major second or whole tone	1.122462:1	200
Minor third	1.189207:1	300
Major third	1.259921:1	400
Perfect fourth	1.334840:1	500
Augmented fourth / Diminished fifth	1.414214:1	600
Perfect fifth	1.498307:1	700
Minor sixth	1.587401:1	800
Major sixth	1.681793:1	900
Minor seventh	1.781797:1	1000
Major seventh	1.887749:1	1100
Octave	2:1	1200

SCALE FACTOR. (1) In **analog computing,** a proportionality factor which relates the magnitude of a variable to its representation within a **computer.** (2) In **digital computing,** the arbitrary factor which may be associated with numbers in a computer to adjust the position of the **radix** so that the significant digits occupy specified columns. (3) A measure of the sensitivity of a **galvanometer** or similar device, defined as the ratio of the current through, or the voltage across, the terminals to the deflection. Identical with **figure of merit (2).**

SCALE, JUST. A musical scale (see **scale, musical**) formed by taking three consecutive triads each having the ratio 4:5:6, or 10:12:15. By consecutive triads is meant triads such that the highest note of one is the lowest note of the other.

Some Just Intervals

Name of Interval	Frequency Ratio	Cents
Unison	1:1	
Semitone	16:15	111.731
Minor tone or lesser whole tone	10:9	182.404
Major tone or greater whole tone	9:8	203.910
Minor third	6:5	315.641
Major third	5:4	386.314
Perfect fourth	4:3	498.045
Augmented fourth	45:32	590.221
Diminished fifth	64:45	609.777
Perfect fifth	3:2	701.955
Minor sixth	8:5	813.687
Major sixth	5:3	884.359
Harmonic minor seventh	7:4	968.826
Grave minor seventh	16:9	996.091
Minor seventh	9:5	1017.597
Major seventh	15:8	1088.269
Octave	2:1	1200.000

SCALE, MUSICAL. A series of notes (symbols, sensations, or stimuli) arranged from low to high by a specified scheme of intervals, suitable for musical purposes.

SCALE OF EIGHT. A **ring counter** which can absorb eight counts before recycling.

SCALE-OF-TWO CIRCUIT. A colloquialism for **bistable circuit.**

SCALE, PYTHAGOREAN. A musical scale (see **scale, musical**) such that the frequency intervals are represented by the ratios of integral powers of the numbers 2 and 3.

SCALER (SCALING CIRCUIT). A device that produces an output pulse whenever a prescribed number of input pulses have been received. A binary scaler produces an output pulse whenever two input pulses have been received. By putting binary scalers in sequence, scales of two, four, eight, sixteen, etc., are obtained. A decade scaler produces an output pulse whenever ten input pulses have been received. By putting decade scalers in sequence scales of ten, hundred, thousand, etc., are obtained.

SCALING COUPLE. A **bistable circuit.**

SCALING FACTOR. The number of input pulses per output pulse of a **scaling circuit.**

SCALING RATIO. The ratio of input pulses to output pulses in a **scaling circuit.**

SCANDIUM. Metallic element. Symbol Sc. Atomic number 21.

SCANNER. In television, a device or means for **scanning.**

SCANNER, FLYING SPOT. A television camera device used predominately for film and slide subjects. The subject is illuminated by a "flying-spot" light-source of constant intensity, developed on the face of a **cathode-ray tube** with a short-persistence **phosphor.** The spot of light is made to follow the conventional **raster** pattern so that a **phototube** receiving transmitted or reflected light from the subject will have a signal output proportional to subject brightness and subject position as required.

SCANNING. (1) The process of analyzing or synthesizing successively, according to a predetermined method, the light values of picture elements constituting a picture area. (2) A periodic motion given to the major lobe (see **lobe, major**) of an antenna.

SCANNING AMPLITUDE, CAMERA. The amplitude of the **scanning** signals which determine the area of the television camera **mosaic** interrogated for signal content. In general practice, as much of the surface is used as possible. However, some adjustments and measurements can best be made with reduced mosaic areas.

SCANNING ANTENNA MOUNT. A mechanical support for an **antenna** which provides mechanical means for **scanning** or **tracking** with the antenna, and means to take off information for indication and control.

SCANNING, CIRCULAR. **Scanning** in which the direction of maximum radiation generates a plane or a right circular cone whose vertex angle is close to 180°.

SCANNING, CONICAL. **Scanning** in which the direction of maximum radiation generates a cone whose vertex angle is of the order of the beam width. Such scanning may be either rotating or nutating, according as the direction of polarization rotates or remains unchanged.

SCANNING DISK. A **nipkow disk,** or, in field-sequential color television, the tricolor wheel used between the camera lens and the subject.

SCANNING, ELECTRON. The periodic deflection of an electron beam across the screen

of a **cathode-ray tube,** following a definite pattern.

SCANNING FREQUENCY, LINE. The rate at which the lines or sections of an image are scanned. Present standards set the rate at 525 horizontal lines for each $1/30$ of a second, or 15,750 per second.

SCANNING, INDIRECT. Essentially the same scanning mechanism as flying-spot scanning (see **scanning, flying-spot**) except that it is accomplished mechanically, as in the older mechanical television systems.

SCANNING, INTERLACED. A scanning process in which the distance from center to center of successively-scanned lines is two or more times the nominal **line width,** and in which the adjacent lines belong to different fields.

SCANNING LINE. A single continuous narrow strip which is determined by the process of **scanning.** In most television systems, the scanning lines which occur during the return intervals are blanked.

SCANNING LINE(S), NUMBER OF. In television, the ratio of line frequency to **frame frequency.**

SCANNING LINEARITY. The uniformity of **scanning speed** during the trace interval. (See **interval, trace.**)

SCANNING LOSS. In a radar system, the **reduction insensitivity** expressed in **decibels** due to **scanning** across a target compared with that obtained when the beam is directed constantly at the target.

SCANNING PATTERN. The pattern followed in the **scanning** process. In television this pattern is called a **raster,** while radar antennas may follow a circular, conical, or rectangular scanning pattern.

SCANNING, RECTANGULAR. A two-dimensional sector scan (see **scanning, sector**) in which a slow sector scan in one direction is superimposed on a rapid sector scan in a perpendicular direction.

SCANNING, RECTILINEAR. The process of **scanning** an area in a predetermined sequence of narrow, straight parallel strips.

SCANNING, SECTOR. Circular scanning (see **scanning, circular**) in which but a portion of the plane or flat cone is generated.

SCANNING, SPIRAL. Scanning in which the direction of maximum radiation describes a portion of a spiral. The rotation is always in one direction.

SCANNING SPOT. The area with which the scanned area is being explored at any instant in the **scanning** process.

SCANNING YOKE. See **deflection yoke.**

SCATTERING. In its general sense, this term means causing the random distribution of a group of entities, or bringing about a less orderly arrangement, either in position or direction. More specifically, the term denotes the change in direction of particles or photons owing to collision with other particles or systems; it may also be regarded as the diffusion of a beam of sound or light (or other electromagnetic radiation) due to the anisotropy of the transmitting medium. For the various kinds of scattering, and the various entities scattered, see the entries which follow.

SCATTERING, ACOUSTIC. The irregular and diffuse **reflection** or **diffraction** of sound in many directions. Scattering frequently occurs when the reflecting surfaces or bodies are small compared with the wavelength of sound, in certain cases the reflecting bodies may be small inhomogeneities in the medium.

SCATTERING AMPLITUDE. A quantity closely related to the intensity of scattering of a wave by a central force field such as that of a nucleus. If e^{ikz} describes an incident plane wave of **wave number** k, then the scattered wave can be expressed as ae^{ikr}/r, at large distances r from the scattering center, where a is the scattering amplitude. The equation $\sigma = 4\pi|a|^2$ relates the scattering amplitude to the scattering cross section σ. These considerations hold for nuclear scattering at moderate energies (roughly below 10 mev), where the scattering is symmetric in the center of gravity system. For higher energies the scattering may not be symmetric, and a must be generalized by expressing it in terms of **Legendre polynomials** in the **scattering angle.**

SCATTERING ANGLE. The angle between the initial and final lines of motion of a scat-

tered particle. It may be specified as applying either to the **laboratory** or **center-of-mass system.**

SCATTERING COEFFICIENT. See discussion of **absorption coefficient.**

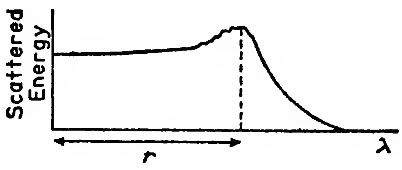
SCATTERING, COHERENT. Scattering, either of particles or photons, in which there are definite phase relations between incoming and scattered waves. Ordinary scattering (see **scattering, Rayleigh**) is of this nature. In coherent scattering interference occurs between the waves scattered by two or more centers. This type of scattering is exemplified by the Bragg scattering of x-rays and the scattering of neutrons by crystals, which gives constructive interference only at certain angles, called **Bragg angles.**

SCATTERING, COMPTON. Elastic scattering (see **scattering, elastic**) of photons by electrons. Because the total energy and total momentum are conserved in the collisions, the wavelength of the scattered radiation undergoes a change that depends in amount on the **scattering angle.** If the scattering electron is assumed to be at rest initially, the Compton shift is given by the following equation:

$$\lambda' - \lambda = \lambda_0(1 - \cos\theta) = (h/m_ec)(1 - \cos\theta),$$

where λ' is the wavelength associated with the scattered photons, λ is the wavelength of the incident photons, λ_0 is the (Compton) wavelength of the electron and θ is the angle between the paths of incident and scattered photons.

SCATTERING CURVE, EXPERIMENTAL. For wavelengths much shorter than the radius of the particles causing the **scattering,** the scattered energy is nearly independent of the wavelength. For wavelengths much longer



than the radius of the particles, the scattered energy falls off as the inverse fourth power of the wavelength (Rayleigh scattering). (See **scattering, Rayleigh.**)

For the case where the particles and the wavelengths are nearly the same, the scattered energy is a maximum. Practical calculations on transmission in this last case are very complicated.

SCATTERING, DELBRÜCK. The scattering of light by a Coulomb field, a process which according to **quantum electrodynamics** occurs as a scattering of the light by the virtual electron-positron pairs produced by the Coulomb field. The total cross-section is approximately 6 millibarns for uranium.

SCATTERING, DOUBLE COMPTON. See **double Compton scattering.**

SCATTERING, ELASTIC. See **collision, elastic.**

SCATTERING FORMULA, MOTT. See **Mott scattering formula.**

SCATTERING, INCOHERENT. Scattering, either of particles or photons, in which the scattering elements act independently so that there are no definite phase relations between different parts of the scattered beam. The intensity of the scattered radiation at any point is determined by adding the intensities of the scattered radiation reaching the point from the independent scattering elements.

SCATTERING, INELASTIC. Scattering brought about by inelastic collisions. (See **collision, inelastic.**)

SCATTERING LOSS. In acoustics, that part of the **transmission loss** which is due to scattering within the medium or due to roughness of the reflecting surface. In electromagnetic waves, the loss in power at the receiving point, due to **scattering.**

SCATTERING MATRIX. The array of observable quantities associated with the scattering of one system by another, $S_{\alpha\beta}$ being the amplitude of the outgoing wave in state β arising from a collision initiated by unit flux in state α. The matrix $S_{\alpha\beta}$ is unitary (see **matrix, unitary**).

SCATTERING, MULTIPLE. Any **scattering** of a particle or photon in which the final displacement is the sum of many displacements, usually small. (See also **scattering, plural.**)

SCATTERING OF ELECTROMAGNETIC RADIATION. When light enters a body of matter, however transparent, part of it is

diffusely reflected or "scattered" in all directions. This is due to the interposition in the light stream of particles of varying size, from microscopic specks down to electrons, and the deflection of light quanta resulting from their encounters with these small obstacles. Similar effects are produced upon infra-red, ultraviolet, x-rays, and other forms of **electromagnetic radiation**, and upon streams of particles such as **cathode rays** or **α-rays**.

SCATTERING OF ELECTRONS IN SOLIDS. An electron in the **conduction band** of a metal or **semiconductor** may be scattered by the **thermal vibrations** of the lattice, by impurities and lattice **defects**, by **dislocations**, by the boundaries of the specimen (as in thin films), and by the disordered structure of an alloy or **solid solution**.

SCATTERING OF NEUTRONS BY PROTONS. The analysis of the scattering of neutrons by protons indicates that the forces between neutrons and protons are identical with those between protons and protons, except for a correction for electrostatic repulsion in the latter case. This supports the concept of **charge independence**.

SCATTERING OF PARTICLES, PROBABILITY OF. When electrons (or atoms) collide with atoms, the resulting scattered current per unit incident current, per unit path length, per unit pressure at 0°C, per unit solid angle in the direction θ is the probability of scattering.

SCATTERING OF PHONONS IN SOLIDS. The transport of heat in solids is limited by scattering of the **thermal vibrations**. The interaction with other **phonons** is mainly effective in **Umklapp processes**. Lattice **defects** appear to act by **Rayleigh scattering**, the effect being inversely as the fourth power of the wavelength. The crystal **boundaries** scatter the phonons, in default of other resistance, the reflection being as if from a rough surface, except at very long wavelengths in very smooth crystals, when **specular reflection** has been observed. In glasses, and other amorphous solids, the scattering may be by local variations in structure, although this also is ineffective at very long wavelengths. In metals the phonons are strongly scattered by the **free electrons**—the inverse of the electrical resistance phenomenon.

SCATTERING OF PROTONS IN HYDROGEN. The results of measurements of the scattering of protons by protons indicate the presence of an attractive nuclear force between the protons at very close contact.

SCATTERING OF PROTONS, INELASTIC. Nuclear scattering of **protons** in which some of the proton energy is transferred to the nucleus, leaving the nucleus in an excited energy state, with the subsequent emission of γ-rays.

SCATTERING OF SOUND, SELECTIVE. Frequency-dependent sound scattering. (See **scattering, acoustic.**)

SCATTERING, PLURAL. Any **scattering** of a particle or photon in which the final displacement is the vector sum of a small number of displacements. Plural scattering may be regarded as intermediate between single and multiple scattering. (See **scattering, single** and **scattering, multiple.**)

SCATTERING, POTENTIAL. (1) In nuclear theory, the part of **nuclear scattering** that has its origin in reflection from the nuclear surface, thus leaving the interior of the nucleus undisturbed. The term usually is used in contradistinction to resonance scattering, which is the scattering arising from the part of the incident wave that penetrates the surface and interacts with the interior of the nucleus. In general, the scattered wave may have components arising from both kinds of scattering processes (2) Scattering of an incident wave by reflection at a change or discontinuity in the potential field.

SCATTERING, RAMAN. See **Raman effect.**

SCATTERING, RAYLEIGH. For very fine dust (or for other fine particles, or even the molecules of the air), Rayleigh concluded that the intensity of the light of wavelength λ, scattered in any direction making an angle θ with the incident direction, is directly proportional to $1 + \cos^2 \theta$ and inversely proportional to λ^4. The latter point is noteworthy in that it shows how much greater is the scattering of the short wavelengths. These relations apply when the scattering particles are much smaller than the wavelength of the radiation. Thus the sky is blue, and tobacco smoke appears blue, because blue light is scattered more than red. The unscattered light is

of course complementary to blue, that is, orange or yellow—which explains the "warm" hues of the sunset. Scattered light is also distinctly plane-polarized. (See **polarized light.**)

SCATTERING, RUTHERFORD. The process in which moving particles, commonly charged particles, are scattered at various angles by interaction with atoms of a solid material. In Rutherford's original work, high speed α-particles from radon were focused in a narrow beam to strike a thin gold foil. Most of them pass through, but some are scattered.

SCATTERING, SINGLE. The deflection of a particle from its original path owing to one encounter with a single scattering center in the material traversed. This is to be distinguished from plural scattering and multiple scattering, which involve successive encounters with scattering centers.

SCATTERING, THOMSON. The scattering of **electromagnetic radiation** by free charged particles, computed either classically or according to non-relativistic quantum theory. Scattering by electrons is interpreted classically as a process in which some of the energy of the primary radiation is reduced because electrons radiate when accelerated in the transverse electric field of the radiation. The scattering cross section is given by

$$\sigma_T = \frac{8}{3}\pi\left(\frac{e^2}{mc^2}\right)^2,$$

which is 0.657 barn for an electron and is called the Thomson cross section, or the classical scattering cross section.

SCAVENGING. The use of an unspecific precipitate to remove from solution by adsorption or coprecipitation a large fraction of one or more undesirable radionuclides. Voluminous gelatinous precipitates are usually used as scavengers, e.g., $Fe(OH)_3$.

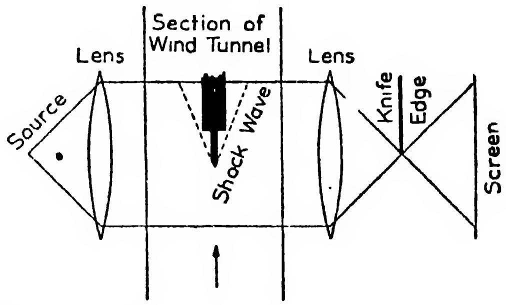
SCHERING BRIDGE. See **bridge, Schering.**

SCHLÄFLI FORMULA. An integral representation of the **Legendre polynomial**

$$P_n(z) = \frac{1}{2\pi i}\int\frac{(t^2-1)^n}{2^n(t-z)^{n+1}}\,dt$$

where the **contour** encircles the point z in the counterclockwise direction in the complex plane.

SCHLIEREN. Any disturbance of the air in the light path of an **interferometer** which changes the density of the air (for example, the heated air rising from a flame) will cause changes in the **interference** pattern. In order to observe the density pattern of the airflow about an obstacle in a wind tunnel, a very large interferometer is mounted to look across the tunnel. Steady flow with constant density



Idealized Schlieren apparatus for observing shock wave in supersonic tunnel

of air does not show on the interference pattern, but turbulent flow, shock waves and similar density variations do appear in the interference pattern. The word "schlieren" is used to describe the whole phenomenon. The interferometer plates are called schlieren plates, the interference pattern is called a schlieren picture, the whole instrument is called a schlieren interferometer or simply schlieren apparatus.

SCHMIDT CORRECTION PLATE. A **corrector plate** placed in front of the reflecting spherical mirror of a telescope so as to eliminate **spherical aberration** and **coma.** Telescopes so made have unusually wide fields of view.

SCHMIDT-HILBERT METHOD. A method of solving **integral equations** with symmetric **kernels.** The result is an infinite series involving **eigenfunctions** and **eigenvalues.**

SCHMIDT LINES; SCHMIDT LIMITS. Two lines in the plot of **nuclear magnetic moment** versus **nuclear spin** that show the relationship to be expected according to the simple form of the **independent particle model.** For nuclides of odd atomic numbers

Z, the magnetic moment of the odd proton can add or subtract from the magnetic moment arising from its orbital motion; addition determines the upper Schmidt line, and subtraction the lower Schmidt line. The two lines are approximately parallel, and show an increase in magnetic moment with increasing spin. For nuclides with an odd neutron, the lack of charge precludes any contribution to the magnetic moment from orbital motion. The Schmidt lines therefore are roughly parallel to the nuclear spin axis, and are spaced apart a distance corresponding to twice the neutron's magnetic moment. Experimentally, it is found that points describing actual nuclides do not lie on the Schmidt lines, but are scattered in the region between them.

SCHMIDT OBJECTIVE. An objective for reflecting **telescopes**, designed to correct the **aberration** of the spherical mirror without introducing the coma (blurring) to which even a parabolic reflector is subject for wide fields. The results are obtained in somewhat the same way that spectacles correct for defects in vision.

The Schmidt objective as originally designed consists of a concave spherical mirror, functioning in the same way as the objective of any reflecting telescope, but with a plate of glass interposed in front of it perpendicular to its axis at its center of curvature. This glass plate is not plane, but has one surface "figured" in such a way that, as the rays pass through it on their way to the mirror, it so modifies their course as to effect almost perfect correction for the spherical aberration and coma which the mirror would otherwise produce. In a later design, the objective consists of two coaxial cylinders of glass, in contact along a plane perpendicular to the axis. The rear surface of the rear piece is spherically convex and is silvered on the outside, thus presenting a concave spherical mirror to the interior of the glass cylinder. The front surface of the front piece, passing through the center of curvature of the mirror, is the correction surface, serving the same purpose as the glass plate in the older design. The reason for using two pieces is that the final real image is of course produced between the mirror and the correction surface; and it is here that the plane of separation is located, so that the small photographic film used may be introduced.

SCHMIDT PROCESS. A method for converting a given set of **vectors** $\mathbf{u}_1, \mathbf{u}_2, \cdots, \mathbf{u}_n$ into an **orthonormal** set $\mathbf{v}_1, \mathbf{v}_2, \cdots, \mathbf{v}_n$. If the length of $\mathbf{v}_i$ is l_i and $\mathbf{e}_i = \mathbf{v}_i/l_i$ is a **unit vector,** the calculation may be performed with the **recursion formula**

$$\mathbf{v}_{i+1} = \mathbf{u}_{i+1} - \sum_{k=1}^{n} (\tilde{\mathbf{e}}_k \mathbf{u}_{i+1})\mathbf{e}_k$$

where $\tilde{\mathbf{e}}_k$ is the **transpose** of $\mathbf{e}_k$. The procedure may also be used for functions. If, for example, the original functions are 1, x, x^2, $\cdots$, defined over the range $x = \pm 1$, the orthonormal set obtained from them by the **Schmidt process** is a set of **Legendre polynomials.**

SCHÖNFLIES CRYSTAL SYMBOLS. A notation for the description of the **symmetry classes** of crystals.

SCHOTTKY DEFECT. A lattice **vacancy** created by removing an ion from its site and placing it on the surface of the crystal. For electric neutrality, the number of **cation** Schottky defects must equal the number of **anion** Schottky defects. The number, n, of Schottky defects is given by

$$\frac{n}{N - n} = C_s e^{-W/kT}$$

where there are N lattice points, and W is the energy required to remove an ion from a lattice point, and then add it to the surface. C_s is a numerical factor of the order of 10^3–10^4.

SCHOTTKY EFFECT. The reduction of the **work function** of a thermionic emitter by the application of an accelerating field at the emitter's surface, which permits currents larger than that which would be predicted by the **Richardson-Dushman equation.** The saturation current predicted by the Schottky effect is

$$I_{th} e^{\epsilon\sqrt{\epsilon E}kT}$$

where I_{th} is the zero field thermionic current, T is cathode temperature in degrees Kelvin, ϵ is the electronic charge, and E is the field intensity at the cathode in volts per meter. (See **Schottky theory.**)

SCHOTTKY THEORY. A theory of the rectification properties of the contact between a metal and a **semiconductor,** which depends on

the formation of a **barrier layer** at the surface of contact. (See **Schottky effect.**)

SCHRÖDINGER EQUATION. The basic equation of **wave mechanics.** It is developed by using the **de Broglie wavelength** in the description of a particle and then associating with the measurement of the energy E or of the x-component of momentum p_x of the particle a differential operator

$$E = i\hbar\frac{\partial}{\partial t} \quad \text{or} \quad p_x = -i\hbar\frac{\partial}{\partial x},$$

where $\hbar$ is the **Dirac h.** The **Hamiltonian function** can be expressed either in terms of total energy or in terms of potential energy and momentum. Expressing it in both ways one obtains:

$$-\frac{\hbar^2}{2m}\nabla^2\psi + V(\mathbf{r})\psi - i\hbar\frac{\partial\psi}{\partial t} = E\psi,$$

where ∇^2 is the **Laplacian,** m the mass of the particle, E, its total energy, and $V(\mathbf{r})$ its potential energy (usually a function of position). This is the time dependent Schrodinger equation for ψ

In many instances, we are interested in the allowed values of E in **stationary states** of the system. Using the **Planck law** we may set $E = h\nu = 2\pi\hbar\nu$ and write

$$\psi = \phi(\mathbf{r})e^{2\pi i\nu t} = \phi(\mathbf{r})e^{iEt/\hbar}$$

where $\phi(\mathbf{r})$ is a function of position only. We then obtain the time independent equation:

$$\left[\nabla^2 + \frac{2m}{\hbar^2}\{E - V(\mathbf{r})\}\right]\phi = 0.$$

It is often found that solutions of the equation exist only for specific **eigenvalues** of E. To each eigenvalue E_n there corresponds an eigenfunction of the coordinates ϕ_n. The probability of finding the particle in a region of volume dV is

$$\int|\phi|^2dV = \int\phi\phi^*dV,$$

assuming that ϕ has been normalized so that the integral over all space is unity. (See also **quantum mechanics, non-relativistic; quantum mechanics, relativistic; Schrödinger representation; simple harmonic oscillator; rotational constant.**)

SCHRÖDINGER-GORDON EQUATION. See **Klein-Gordon equation.**

SCHRÖDINGER REPRESENTATION. Representation of the equations of motion in **quantum mechanics** and quantized field theory (see **field theory, quantized**) where the axes of **Hilbert space** are kept constant and the motion of the dynamical system is described by the way in which the vector representing the state varies with time. This time variation of the state vector is described by the wave equation determined by the **Hamiltonian** of the system. This method of developing the consequences of quantum mechanics is called **wave mechanics.** (See **Heisenberg representation; interaction representation.**)

SCHULZE-HARDY RULE. A generalization derived from certain work on **colloidal** systems, to the effect that ions of sign opposite to that of a given colloidal particle are most effective in coagulating it, and that their coagulating power increases with increasing ionic charge. There are however many exceptions to the rule.

SCHUMANN PLATES. The gelatin of conventional photographic plate emulsion is not transparent to the further ultraviolet. For use with ultraviolet radiation shorter than about 2200 A, Schumann developed a method for holding the silver halide to the glass by the use of so little gelatin that the plates may be used down to 1200 A.

SCHUSTER-GANNON METHOD FOR MECHANICAL EQUIVALENT OF HEAT. This method is similar to that of **Griffiths,** except that instead of the resistance, the current is measured

SCHUSTER METHOD. A method of focusing a prism spectroscope (see **spectroscope, prism**) without use of a Gauss eyepiece (see **eyepiece, Gauss**) or a distant object.

SCHWARTZ INEQUALITY. If **A**, **B** are two **vectors** in three-dimensional space and A, B are their **scalar** magnitudes, $AB \geqq \mathbf{A}\cdot\mathbf{B}$, the latter term being the **scalar product.** The relation also applies to n-dimensional space or to continuous regions of space but in the latter case the vectors are replaced by definite integrals.

SCHWARZSCHILD ANASTIGMAT. A **Gregorian** type of reflecting **telescope** with the surfaces so modified as to reduce **astigmatism.**

SCHWARZSCHILD SOLUTION. A rigorous solution of the field equations of general relativity theory (see **relativity theory, general**) for a field generated by a point mass. From it may be derived numerical values for the rotation of the **perihelion of Mercury** and for the **bending of light** in passing near a star.

SCINTILLATION. A flash of light produced in a **phosphor** by an **ionizing event.**

SCINTILLATION COUNTER. See **counter, scintillation.**

SCINTILLATION SPECTROMETER. A **scintillation counter** adapted to the study of energy distributions.

SCLEROMETER. An apparatus for determining the hardness of a material by measuring the pressure on a standard point that is required to scratch the material

SCLEROSCOPE. An apparatus for determining the hardness of a material by measuring the rebound of a standard ball dropped on it from a fixed height.

SCOPHONY TELEVISION SYSTEM. An early British mechanical television system utilizing a **Kerr cell** as a light shutter, and a rotating-mirror system for **scanning.**

SCOPOMETER. An instrument for making **turbidimetric** or **nephelometric** measurements by the contrast between a field of constant brightness and an illuminated line placed behind the solution under test.

SCOPOMETRY. A system of **turbidimetry** or **nephelometry** based on the use of the **scopometer.**

SCOTOPIC VISION. Vision that takes place through the medium of the rods of the retina only, and therefore represents a very low level of **luminance.**

SCRAM. (1) Sudden shutting down of a nuclear reactor, usually by dropping of safety rods. This may be arranged to occur automatically at a predetermined **neutron flux** or under other dangerous conditions, the reaching of which causes the **monitors** and associated equipment to generate a scram signal. (2) To shut down a reactor by causing a scram.

SCRAMBLED SPEECH. See **inverted speech; secrecy systems.**

SCRAMBLER CIRCUIT. See **circuit, scrambler.**

SCREEN GRID. A grid placed between a **control grid** and an **anode,** and usually maintained at a fixed positive potential, for the purpose of reducing the electrostatic influence of the anode in the space between the screen grid and the **cathode.**

SCREEN-GRID CHARACTERISTIC. See **electrode characteristic.**

SCREEN-GRID CURRENT. See **electrode current.**

SCREEN-GRID MODULATION. See **modulation, screen-grid.**

SCREEN PROCESSES. Processes of color photography in which color analysis and synthesis are carried out additively by the use of a mosaic screen of minute primary color filters. The screen may be composed of color filters in the form of a regular geometric pattern, or it may be an irregular mosaic. In either case the screen is between the color-sensitive photographic emulsion and the camera lens during analysis so that the resulting effect in the emulsion is that of three color-separation negatives side by side, completely intermingled by means of the screen's pattern.

SCREENING CONSTANT. (1) A quantity occurring in the relationship between the frequency of a line in a particular **x-ray series,** and the **atomic number** of the element emitting the rays, of the form:

$$\sqrt{\nu} = a(Z - \sigma)$$

in which ν is the frequency of the line, a is a constant, Z is the atomic number of the element, and σ is the screening constant, that is the same for all the lines in a given series. (2) See **screening of nucleus.**

SCREENING NUMBER. A synonym for **screening constant.**

SCREENING OF NUCLEUS. The reduction of the electric field about a nucleus by the **space charge** of the surrounding elec-

trons. The **screening constant** of an element is the **atomic number** minus the apparent atomic number that is effective for a given process.

SCREW AXIS. A type of **symmetry element** possessed by certain **space groups**, in which the lattice is unaltered after a rotation about the axis, and a simultaneous translation along it.

SCREW, CAPACITIVE. See **post, capacitive.**

SCREW, INDUCTIVE. See **post, inductive.**

SCREWS, TUNING. See **tuning screws.**

SEA BREEZE. When coastal land is heated considerably by the sun, a sea breeze springs up, blowing off the cool water onto heated land. A pure sea breeze is usually not more than 1500 ft deep, above which there is a weak returning anti-sea breeze.

SEA LEVEL. The mean level of the oceans

SEARCH COIL. A small coil used to measure **induction** by virtue of the change of **flux** through the coil when it is moved from one position to another or rotated, or when the flux through it is changed by such means as the interruption of the current in the windings of an electromagnet.

SECOND. (1) Unit of time, abbreviation S, s, or sec One 86,400th part of a mean solar day. (2) The international Astronomical Union defines the second as the fraction 1/31,556,925.975 of the length of the tropical year for 1900. The tropical year is the period of revolution of the earth relative to the Vernal Equinox or First Point of Aries (3) Unit of angle, abbreviation ″. One sixtieth part of a minute, or one 3600th part of a degree.

SECOND ANODE. The principal pre-deflection, **accelerating anode** in an electrostatically focused **cathode-ray tube**, the first anode being the focusing electrode or second grid.

SECOND-CHANNEL ATTENUATION. See **selectance.**

SECOND DETECTOR. The detector in an a-m **superheterodyne receiver** which demodulates the **intermediate frequency signal** to recover the original **modulating signal.**

SECOND QUANTIZATION. Process by which a classical field (see **C-number theory**) is analyzed as an ensemble of particles. The field variables (**electromagnetic potentials, or wave functions**) are regarded as operators on which are imposed **commutation rules.** These operators then describe the processes of emission or absorption of light quanta or particles.

SECOND RADIATION CONSTANT. See **Planck distribution law.**

SECONDARY BOW. A faint **rainbow** which sometimes appears outside the brighter primary bow, and has its colors reversed. The reds of the two bows are toward each other.

SECONDARY CELL. See **cell, secondary.**

SECONDARY COSMIC RAYS. Radiation or particles produced in the earth's atmosphere or elsewhere as the result of the interaction of primary **cosmic rays** with atmospheric nuclei and electrons.

SECONDARY ELECTROMAGNETIC CONSTANTS. In transmission line theory, the **propagation constant** and the characteristic impedance (see **impedance, characteristic**) are important secondary constants. In three dimensional theory, the important constants are the intrinsic propagation constant σ, and the intrinsic impedance η, defined by

$$\sigma = \sqrt{i\omega\mu(g + i\omega\epsilon)}, \quad \eta = \sqrt{\frac{i\omega\mu}{g + i\omega\epsilon}},$$

where μ and ϵ are the **permeability** and the **permittivity**, respectively, g is the specific **conductivity**, and ω is the radian **frequency** of the wave. These characteristics of the medium do *not* depend on the geometry of the wave

SECONDARY EMISSION. This term refers to the result of any of several different processes, in each of which some kind of "primary" emission, when it encounters some form of matter, gives rise to another emission of the same or of different character.

The most familiar example of a secondary emission is the **x-rays**, which have their origin in the impacts of high-speed electrons (cathode rays) upon atoms of matter. The resulting x-rays may themselves act, in turn, as the primary emission and, falling upon solid bod-

ies, cause a secondary x-ray emission. Or they may fall upon a fluorescent substance (see **luminescence**) and give rise to a secondary radiation of visible light. X-rays, ultraviolet, or light, falling upon a photosensitive metal, may cause a secondary emission of photoelectrons. (See **photoelectric phenomena.**) The "recoil" electrons from the Compton scattering of x-rays constitute one form of secondary emission. (See **Compton effect.**) (Cf. **secondary radiation.**)

The most common use of the term denotes the emission of electrons from a solid as the result of the collision of higher energy electrons with the solid.

SECONDARY FLOW. See **flow, secondary.**

SECONDARY FOCUS. See **astigmatic focus.**

SECONDARY FRONT. See **front, secondary.**

SECONDARY GRID EMISSION. See **grid emission, secondary.**

SECONDARY OF TRANSFORMER. A **transformer** winding connected to a load. An energized winding is called a "primary."

SECONDARY RADIATION. Particles or photons produced by the interaction with matter of a radiation regarded as primary. Examples are **secondary cosmic rays, photoelectrons, Compton recoil electrons, delta rays,** the electrons liberated from a **dynode** of a **photomultiplier tube** when struck by an electron accelerated from the preceding dynode, recoil protons from neutron-proton collisions, and **bremsstrahlung** radiation. (See **radiator; transition effect.**)

SECONDARY WAVES. See **Huygens principle.**

SECRECY SYSTEMS. In much of the two-way radio telephone links it is highly desirable to make the transmission secret. Since the radiated energy may be picked up by any **receiver** tuned to its frequency and in its path, the transmission must be altered so it is unintelligible to anyone not having the necessary equipment to restore it to its original form. Not only is the equipment necessary, but these secrecy systems can be decoded only by a receiving station having the key to the original alterations. There are several methods of scrambling or altering speech transmissions so they will be unintelligible to the ordinary receiver. One method is to produce the usual amplitude **modulation** on some frequency other than that of the final **carrier.** All but one **sideband** of this modulation is discarded and this sideband is then modulated upon the desired carrier in such a manner as to invert the frequencies, i.e., the low frequencies now appear as highs and vice versa. Another method is to divide the audio band into narrow bands by using **filters** and then interchange them, or invert each band separately. Other modifications involve varying time delays for the various bands.

SECTION MODULUS. An inspection of **flexure** will reveal that the stress in a member subjected to a transverse bending is directly proportional to the external bending moment, and inversely proportional to the ratio of

$$\frac{\text{moment of inertia of cross section}}{\text{distance of the farthest stressed element from the neutral axis.}}$$

It is apparent that this ratio is entirely a property of the shape and size of the cross-section of the structural member. This ratio is known as the section modulus, and is an important property of rolled steel sections and other shapes which are used as structural members. When the bending moment to be withstood by a beam or column is divided by this section modulus, the quotient is the maximum bending stress which will exist in that member.

SECTOR SCANNING. See **scanning, sector.**

SECTOR DISK. A device widely used in physical apparatus to secure an accurately known control of the intensity of a beam of light or other emission. The simplest form is a circular, opaque disk with a sector or sectors, of any desired angle, cut from it. If the disk is interposed in the path of light rays, and rotated rapidly about its center, the resulting intensity, as judged visually, is reduced to a fraction equal to the ratio of the area of the open sectors to that of the whole disk. This arrangement is useful, for example, in a photometer where it is desired to cut down the intensity of one beam to match that of another. By giving the sides of the openings suitable curved shapes instead of cut-

ting them along radii, the intensity may be varied from center to circumference in accordance with any desired law. This affords, for example, a non-selective "wedge" for certain photometric purposes. When a sector disk is used in connection with photographic work, regard must be had for the so-called "intermittency effect," which renders the ratio not strictly accurate.

Sector disks are also used to give a periodicity to a radiation beam which falls on a detector (**thermocouple, photoconductive detector,** etc.) so as to give an alternating current output which can be amplified by a-c methods and also be independent of any unmodulated stray radiation which may reach the detector.

SECTOR, WARM. That sector of a **wave cyclone** occupied by the warmer **air mass.** A warm sector is always smaller than the cold sector which is occupied by the colder air mass.

SECTORAL HORN. See **horn, sectoral.**

SECULAR DETERMINANT. An equation of the form

$$y(\lambda) = |a_{ij} - b_{ij}\lambda| = 0,$$

which becomes a **polynomial** in λ when the **determinant** is expanded. The **roots** of the polynomial are usually **eigenvalues** of some classical or quantum mechanical problem.

SEDIMENTATION. The process of settling, commonly of solid particles from a liquid.

SEDIMENTATION CONSTANT. A quantity obtained in investigating the behavior of **colloidal particles** under the action of forces, chiefly centrifugal forces. This quantity for a given particle and medium is defined by the expression:

$$S = \frac{2r^2(\rho - \rho')}{9\eta}$$

in which S is the sedimentation constant, r is the radius of the particle, p and p' are the reciprocals of the partial specific volumes of particle and medium, respectively, and η is the **viscosity** of the medium.

SEEBECK EFFECT. (1) The **electromotive force** given by two contacting metals which make a closed electrical circuit having two junctions at different temperatures The magnitude of the electromotive force depends upon the metals, and upon the temperature-difference between the two contacts. (See also **Peltier effect**; and **thermoelectric phenomena.**) (2) Seebeck observed that if a photographic emulsion is exposed to the point at which a visible image appears faintly, and is then exposed to colored light, the emulsion assumes the color of the light to which it is exposed. The colors, however, are weak and mixed with gray. Many attempts have been made to perfect processes of color photography of this character, but without success.

SEGER CONES. Small cones used for indicating furnace temperatures, especially in the ceramic industries. They are prepared of mixtures of clay, salt, and other materials in various proportions, such that the softening points of the cones vary progressively in the series, so that they can be used to indicate temperatures through a considerable range.

SEISMIC DETECTORS. Any microphone connected to recording **oscillographs** and located in a strategic position on the earth's surface to detect **acoustic waves** transmitted through the earth. Interest is usually confined to frequencies below 100 cycles/sec.

SEISMOGRAPH. An instrument for recording earth tremors; usually housed for the purpose in a suitable seismological observatory. There are two classes of seismograph, one for recording horizontal and the other for recording vertical components of vibration. A well-equipped observatory has three, a north-south horizontal, an east-west horizontal, and a vertical recorder The instruments are somewhat complicated, but the principle is that of a heavy mass poised in such a way that a vibration of its support, together with the inertia of the mass, causes a relative motion of mass and support; and this motion, suitably amplified, produces the record. In the older forms the recording was done mechanically by a stylus tracing on a revolving drum; in more modern types an electromagnetic current, generated by the motion, operates a **galvanometer** which, by means of a beam of light reflected from its mirror, produces a photographic record of the earth's vibration on a moving film.

SELECTANCE. The reciprocal of the ratio of the **sensitivity** of a receiver tuned to a specified channel to its sensitivity at another

channel separated by a specified number of channels from the one to which the receiver is tuned. Unless otherwise specified, selectance should be expressed as voltage or field-strength ratio. Selectance is often expressed as "adjacent-channel attenuation" (ACA) or "second-channel attenuation" (2ACA).

SELECTION RULES IN ATOMIC SPECTRA. It was found early in the study of atomic spectra that radiative transitions between certain pairs of **stationary states** seldom or never occur. A set of rules which are expressed in terms of the differences of the quantum numbers of the two states involved allow a prediction of allowed transitions and **forbidden transitions.** The conditions for allowed transitions are:

$$\Delta L \text{ (orbital angular momentum)} = \pm 1$$

$$\Delta J \text{ (total angular momentum)} = 0 \text{ or } \pm 1,$$

$$\Delta M \text{ (magnetic orientation)} = 0 \text{ or } \pm 1$$

The selection rules are not rigorously obeyed. In atoms which do not exhibit Russell-Saunders **coupling,** the quantum numbers L and S are not defined. Even in atoms which do have this type of coupling, forbidden transitions are merely of lower probability than allowed ones and may occur from a state from which no transitions are allowed by the rules if conditions are such that **collisions of the second** kind do not remove the atom from the initial state before it radiates (e.g., at extremely low pressures).

SELECTION RULES, NUCLEAR. A set of statements that serve to classify transitions of a given type (emission or absorption of radiation, β-decay, and so forth) in terms of the **spin** and **parity** (I and π) **quantum numbers** of the initial and final states of the systems involved in the transitions, in such a way that transitions of a given order of inherent probability (after making allowance for the influence of varying energy, charge and size of system, and so forth) are grouped together. The group having highest probability of taking place per unit time is said to consist of allowed transitions; all others are called **forbidden transitions.** Table 1 lists the selection rules for radiative transitions: each entry gives the character (E = electric, M = magnetic) and the multipole order (1 for dipole, 2 for quadrupole, 3 for octopole, . . .) of the predominant radiation mechanism for the indicated spin change ΔI and parity change $\Delta\pi$; the entry "none" means that radiative transitions are strictly forbidden.

TABLE 1

$\Delta\pi$	ΔI						
	0 $I = 0$	0 $I \neq 0$	1	2	3	4	5
No	None	$M1$	$M1$	$E2$	$M3$	$E4$	$M5$
Yes	None	$E1$	$E1$	$M2$	$E3$	$M4$	$E5$

Table 2 lists the selection rules for β-decay: the entry A means that for the indicated spin and parity change the transition is allowed; I, means that it is first forbidden; II, second forbidden . . .

TABLE 2

$\Delta\pi$	ΔI						
	0	1	2	3	4	5	6
No	A	4	II	II	IV	IV	VI
Yes	I	I	I	III	III	V	V

Fermi selection rules and Gamow-Teller (GT) selection rules are alternative sets of rules for allowed β-transitions; both are currently believed to be valid, so that a transition allowed according to either set is actually allowed.

SELECTIVE FADING. See **fading, selective.**

SELECTIVE RADIATOR. An emitter of radiation yielding radiation of different spectral energy distribution from that of a **black body** at the same temperature.

SELECTIVITY (OF A RECEIVER). That characteristic which determines the extent to which the receiver is capable of differentiating between the desired signal and disturbances of other frequencies.

SELECTOR. A circuit selecting only that portion of a waveform having certain characteristics of amplitude, frequency, phase, or time of occurrence.

SELECTOR PULSE. A **pulse** used to actuate a **time selector.**

SELECTRON. Trade name for a grain-oriented, silicon-iron magnetic alloy.

SELENIUM. Nonmetallic element. Symbol Se. Atomic number 34.

SELENIUM CELL. In general, an arrangement in which is mounted a thin film of selenium, with electric terminals, for utilizing the **photoconductive** property of selenium Specifically, (1) a photovoltaic cell utilizing **selenium** as one of the **barrier** materials, (2) a rectifier element utilizing a **barrier layer** formed between specially treated crystallized selenium and an alloy of cadmium. The selenium is placed on a sheet of steel or aluminum which serves as a mounting and heat transfer medium.

SELF-ABSORPTION (SELF-REVERSAL). The reduction in **radiant power** at the center of emission lines, resulting from selective absorption of **radiation** emitted by the hot central core into the cooler outer vapor of the source envelope.

SELF-BIAS. See **cathode bias.**

SELF-CHARGE. Extra contribution to the electric charge of a charged particle due to **vacuum polarization** arising from the field produced by the original charge. The self-charge and the "original" charge cannot be distinguished experimentally, and the process of identifying their sum with the observed charge is called charge renormalization This program, together with that of **renormalization of mass** enables one to avoid many of the difficulties arising from divergent integrals which appear in computations of processes according to quantized field theory. (See **field theory, quantized.**)

SELF-CONSISTENT FIELD METHOD (ALSO CALLED HARTREE METHOD). A method of treating the problem of the many-electron atom in which the **eigenfunction** for the system is represented as the product of Z single-electron functions which must satisfy the following condition: The effective field which is in accord with the assumed charge density distribution function for any one electron (that is, represents a solution of the corresponding **Schrödinger equation** for a given form of the **potential energy function**) must be consistent with the field deduced from the charge density distribution due to all the other electrons.

SELF-ENERGY OF A PARTICLE. Classically, the energy of interaction between different parts of the particle (considered, for example, as a ball of charge). In quantized field theory (see **field theory, quantized**) the contribution to the **Hamiltonian** arising from the virtual emission and absorption of other particles, especially **photons** or **mesons.**

SELF-INDUCTANCE. The ratio of the **magnetic flux** linking a circuit to the flux-producing current in that circuit. (See **energy of a system of current circuits.**)

SELF-PULSE MODULATION. See **modulation, self-pulse.**

SELF-QUENCHED COUNTER TUBE. See **counter tube, self-quenched.**

SELF-QUENCHING DETECTOR. See **detector, self-quenching.**

SELF-SATURATING CIRCUIT. A magnetic amplifier circuit of the type which employs self-saturation.

SELF-SATURATION. Self-saturation in a magnetic amplifier refers to the connection of half-wave rectifying circuit elements in series with the output windings of the saturable reactors.

SELF-SHIELDING. (1) The self-absorption of radiation by the source of radiation. (2) In nuclear **reactor** terminology, the **shielding** of one part of a region from particles or radiation arising in another part.

SELLMEIER EQUATION. An equation expressing the relationship between the **refractive index** of a medium and the **wavelength** of the light; this variation of refractive index with wavelength is known as **refractive dispersion.** The equation is of the form

$$n^2 = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} + \cdots$$

in which n is the index of refraction, and λ is the wavelength. This equation is the same as the **Cauchy formula.**

SELSYN. A General Electric Company trade name for the universal term **synchro.**

SEMICONDUCTOR. An electronic conductor whose resistivity at room temperature is in the range 10^{-2} to 10^{9} ohm-cm (which is between metals and insulators), in which the electrical charge **carrier** concentration increases with increasing temperature over some temperature range. Certain semiconductors possess two types of carriers, namely negative electrons and positive **holes.** The essential difference between a semiconductor and a metal is that, according to the **band theory of solids,** the number of free electrons in the former is very small, the energy bands being either entirely full or entirely empty, except for a few electrons and **holes** created by thermal excitation **(intrinsic semiconductor)** or by the presence of impurities Important semiconducting materials include Si, Ge, Se, Cu_2O, PbTe, PbS, SiC, etc., and their uses are manifold in such devices as **rectifiers, modulators, detectors, thermistors, photocells** and **transistors.**

SEMICONDUCTOR, COMPENSATED. A **semiconductor** in which one type of **impurity** or **imperfection** (e.g., **donor**) partially cancels the electrical effects of the other type of impurity or imperfection (e.g., **acceptor**).

SEMICONDUCTOR, DEGENERATE. A **semiconductor** in which the number of electrons in the **conduction band** is so high that they must be described by **Fermi-Dirac statistics,** as in a metal.

SEMICONDUCTOR DEVICE. An electron device in which the characteristic distinguishing electronic conduction takes place within a **semiconductor.**

SEMICONDUCTOR DEVICE, MULTIPLE UNIT. A **semiconductor device** having two or more sets of electrodes associated with independent **carrier** streams. It is implied that the device has two or more output functions which are independently derived from separate inputs, e.g., a duo-triode transistor.

SEMICONDUCTOR DEVICE, SINGLE UNIT. A **semiconductor** device having one set of electrodes associated with a single **carrier** stream. It is implied that the device has a single output function related to a single input.

SEMICONDUCTOR, EXTRINSIC. A **semiconductor** with electrical properties dependent upon **impurities.**

SEMICONDUCTOR, IMPURITY. A **semiconductor** whose properties are due to the presence of foreign atoms, giving rise to **impurity levels.** Such materials are very useful, since their electrical properties can be profoundly altered by changing the concentration and type of impurity. (See also **band theory of solids.**)

SEMICONDUCTOR, INTRINSIC. A material which is naturally semiconducting, in the form of its pure, ideal crystal even when entirely free of impurities. All **semiconductors** have this property, but it may be very small compared with the impurity semiconductor, and only to be observed at high temperatures It is to be described, according to the **band theory of solids,** by the thermal excitation of electrons from the filled band the whole width of the **energy gap** to the conduction band.

SEMICONDUCTOR, N-TYPE. An extrinsic semiconductor (see **semiconductor, extrinsic**) in which the conduction electron (see **electron, conduction**) density exceeds the **hole** density. It is implied that the net ionized **impurity** concentration is **donor** type. (See also **band theory of solids.**)

SEMICONDUCTOR, P-TYPE. An extrinsic semiconductor (see **semiconductor, extrinsic**) in which the **hole** density exceeds the conduction electron density (see **electron, conduction**). It is implied that the net ionized **impurity** concentration is **acceptor** type. (See also **band theory of solids.**)

SEMI-EMPIRICAL MASS FORMULA. See **mass formula, semi-empirical.**

SEMIPERMEABLE MEMBRANE (SEMIPERMEABLE DIAPHRAGM). A membrane or septum through which a solvent but not certain dissolved or colloidal substances may pass, used in **osmotic pressure** determinations. Many natural membranes are semipermeable, e.g., cell walls; other membranes may be made artificially, e.g., by precipitating copper ferrocyanide in the interstices of a porous cup, the

cup serving as a frame to give the membrane stability.

SEMIREMOTE CONTROL. A system or method of radio-transmitter control whereby the control functions are performed near the **transmitter** by means of devices connected to, but not an integral part of the transmitter.

SEMITONE (HALF-STEP). The interval between two sounds whose basic frequency ratio is approximately equal to the twelfth root of two. The interval, in equally tempered semitones, between any two frequencies, is 12 times the logarithm to the base 2 (or 39.86 times the logarithm to the base 10) of the frequency ratio. (See **scale, equally-tempered; scale, just.**)

SEMI-TRANSPARENT PHOTOCATHODE. A photocathode in which radiant flux incident on one side produces photoelectric emission from the opposite side.

SENDING-END IMPEDANCE. The input impedance (see **impedance, input**) of a **transmission line.**

SENSATION LEVEL. See **level above threshold.**

SENSATION UNIT. (See also **level above threshold.**) A unit of **loudness.** One sensation unit is equal to 20 $\log_{10} p$, where p is the excess pressure.

SENSITIVE TIME. The duration of supersaturation adequate for **track formation** following expansion of a **cloud chamber.**

SENSITIVE VOLUME. That portion of a **counter tube** or **ionization chamber** which responds to a specific radiation.

SENSITIVITY. In general, susceptibility to external action, as measured by speed of response or degree of responsiveness, as exemplified by sensitivity to light or other radiation, or sensitivity to electric current. Specific usages are: (1) The ratio of output response to a specified change in the measured variable. (2) The least signal input capable of causing an output signal having desired characteristics; thus the sensitivity of a **camera tube** is the signal current developed per unit incident radiation density (i.e., per watt per unit area). Unless otherwise specified the radiation is understood to be that of an unfiltered incandescent source of 2870°K, and its density, which is generally measured in watts per unit area, may then be expressed in **foot-candles.** (3) The sensitivity of a **receiver** is the signal input necessary for the receiver to produce a standard output. The amount of the output, the audio-frequency used to **modulate** the input and the degree of **modulation** should be specified. (4) The current sensitivity of a **galvanometer** is the ratio of deflection to galvanometer current. (5) The sensitivity (or sensitiveness) of a **balance** is the smallest mass to which it can respond. (6) The sensitivity (or sensitiveness) of an analytical method is the minimum quantity of a substance which can be detected. (7) The sensitivity of a **voltmeter** is the ratio of its resistance to its full-scale reading, i.e., the inverse of the moment necessary to produce full scale deflection.

SENSITIVITY, CONTRAST. See **contrast sensitivity.**

SENSITIVITY, DYNAMIC. For **phototubes,** the ratio of alternating anode current to the alternating component of total incident flux.

SENSITIVITY, MAXIMUM, IN FM SYSTEMS. The least signal input that produces a specified output power.

SENSITIVITY, MAXIMUM-DEVIATION, IN FM RECEIVERS. Under maximum system deviation, the least signal input for which the output distortion does not exceed a specified limit.

SENSITIVITY, QUIETING, IN FM RECEIVERS. The least signal input for which the output **signal-to-noise ratio** does not exceed a specified limit.

SENSITIVITY, THRESHOLD. The lowest level of the measured variable which produces effective response of the instrument or automatic controller.

SENSITOMETRY. Sensitometry is concerned primarily with the measurement of photographic **sensitivity;** however, in the broader sense it is concerned with the measurement of the response of photographic materials upon exposure to light or other forms of radiant energy, under specified conditions of exposure and development.

SEPARATION CIRCUIT. See **circuit, separation.**

SEPARATION ENERGY. A synonym for **binding energy** of a proton, neutron, or α-particle within a nucleus.

SEPARATION FACTOR. The ratio of the abundance ratio of two isotopes after processing to their abundance ratio before a process or operation. It is given by the following equation:

$$r = \frac{n_1'/n_2'}{n_1/n_2}$$

where n_1 and n_2 are the initial mole fractions of isotopes of mass numbers m_1 and m_2 respectively, and n_1' and n_2' are the corresponding quantities after processing.

SEPARATION OF FLOW. See **flow, separation of.**

SEPARATION OF ISOTOPES, BARRIER DIFFUSION METHOD. A method of separation in which a gas that is an isotopic mixture is allowed to diffuse through a porous wall or barrier. Separation of the various isotopes is based on the principle that the lighter molecules, M_1, diffuse through the porous wall more readily than the heavier molecules, M_2.

SEPARATION OF ISOTOPES, CENTRIFUGAL METHOD. A method of separating **isotopes** which is based on the fact that if a gas or vapor flows into a rapidly-rotating cylinder, the force acting on the molecules will result in an increased concentration of the heavier isotope at the walls, while the lighter isotope tends to collect nearer the axis of rotation.

SEPARATION OF ISOTOPES, CHEMICAL EXCHANGE. A method of separating **isotopes** which makes use of the fact that the chemical properties of the different isotopes of an element are often slightly different. Thus, in a system consisting of NH_3 gas in equilibrium with a solution of ammonium nitrate, containing NH_4^+ ions, N^{15} tends to concentrate in the ammonium nitrate solution, while the NH_3 gas contains relatively more N^{14}.

SEPARATION OF ISOTOPES, DISTILLATION METHOD. The separation of isotopic species by fractional distillation is possible when their vapor pressures or boiling points are sufficiently different. For example, heavy water (D_2O) boils at a temperature about 1.4°C higher than ordinary water (H_2O); this makes the separation of D^2 from H^2 by fractional distillation possible.

SEPARATION OF ISOTOPES, ELECTROLYSIS METHOD. The separation of isotopes by electrolytic decomposition of a solution, as in the electrolysis of water for the concentration of deuterium. The method depends on the differing rates of discharge of isotopic ions, and hence is a function of the chemical properties of the different isotopes.

SEPARATION OF ISOTOPES, ELECTROMAGNETIC METHOD. Any method of separating **isotopes** which uses electric and magnetic fields to accelerate and focus ions according to their masses, in the manner of a **mass spectrograph.**

SEPARATION OF ISOTOPES, GASEOUS DIFFUSION METHOD. A method of separating **isotopes** which makes use of the different rates of diffusion of gases through another gas, the theoretical rate being a function of the molecular mass

SEPARATION OF ISOTOPES, ION MOBILITY METHOD. A process of separation based on the difference in mobility of different ions in an electrolytic solution under the influence of an electric field.

SEPARATION OF ISOTOPES, THERMAL DIFFUSION METHOD. A method of separating **isotopes** which makes use of the fact that if a gaseous mixture of isotopes is placed in a temperature gradient, the lighter molecules tend to concentrate in the regions of higher temperature.

SEPARATION OF VARIABLES. A method of finding a particular solution to a linear **partial differential equation.** Assume a solution which is the product of functions each depending on a single one of the independent variables. Substitution of this product into the original differential equation often results in an equation in which some terms are functions of only one variable, while other terms do not involve this variable. Each term involving a single variable may then be set equal to a constant. The original equation has then been separated into several ordinary differential equations which may then be solved by the usual methods. The constants

of integration furnish enough parameters to satisfy any imposed boundary conditions.

The procedure is particularly useful for the equations which occur in physical problems. For example, for **Laplace's equation** in Cartesian coordinates

$$\nabla^2\phi = \frac{\partial^2\phi}{\partial x^2} + \frac{\partial^2\phi}{\partial y^2} + \frac{\partial^2\phi}{\partial z^2} = 0,$$

assume $\phi(x,y,z) = X(x)Y(y)Z(z)$ and the particular solution becomes

$$\phi(x,y,z) = \exp(kx + ly + mz),$$

where $k^2 + l^2 + m^2 = 0$.

SEQUENCE. A set of quantities $s_1, s_2, \cdots, s_n, \cdots$, called **elements,** which can be arranged in an order so that when n is given the nth member of the **sequence** s_n is completely specified. The elements are usually arranged by matching them up, one by one, with the positive integers $1, 2, 3, \cdots, n, \cdots$ A common symbol for a sequence is $\{s_n\}$. It could be **bounded** or **unbounded; convergent** or **divergent.** The common types of sequences are **infinite series; infinite products; infinite continued fractions.**

SEQUENCE, BOUNDED. Let N be an arbitrary positive number If it can be chosen so that $N > |s_n|$ for all absolute values of the members of a **sequence,** then the sequence is **bounded.** If there is at least one $|s_n| \geqq N$ it is **unbounded.**

SEQUENCE, CONVERGENT. A sequence which approaches a **limit.**

SEQUENCE, DIVERGENT. Any **sequence** which is not convergent.

SEQUENTIAL CONTROL. The manner of operation in which instructions to a **digital computer** are set up in sequence and are fed consecutively to the computer during the solution of a problem.

SEQUENTIAL CONTROL, DYNAMIC. A method of operation in which a **digital computer,** as the computation proceeds, can alter instructions, or the sequence in which instructions are executed, or both.

SERIAL TRANSMISSION. See **transmission, serial.**

SERIES. An expression of the form $a_1 + a_2 + a_3 + \cdots + a_n + \cdots$ which may have a finite or an infinite number of terms. Its partial sums constitute the **sequence** $\{s_n\}$, where $s_1 = a_1;\ s_2 = a_1 + a_2;\ \cdots;$

$$s_n = \sum_{k=1}^{n} a_k.$$

SERIES, ALTERNATING. A **series** with alternate positive and negative terms, such as $a_0 - a_1 + a_2 - a_3 \pm \cdots$.

SERIES, ARITHMETIC. The sum of an **arithmetic progression.** If there are n terms in the series, its sum $S_n = \frac{1}{2}n(a + l) = \frac{1}{2}n[2a + (n-1)d]$ where a is the first term, d is the difference between terms, l is the last term.

SERIES, ASYMPTOTIC. A **divergent** series of the form

$$A_0 + \frac{A_1}{x} + \frac{A_2}{x^2} + \cdots + \frac{A_n}{x^n} + \cdots.$$

It is an asymptotic representation of a function $f(x)$ if

$$\lim_{x \to \infty} x^n[f(x) - S_n(x)] = 0$$

for any value of n, where $S_n(x)$ is the sum of the first $(n + 1)$ terms of the series.

SERIES, BINOMIAL. The infinite **series** representation of $(x + y)^n$ where n is not zero or a positive integer. It is usually given in the form

$$(1 + z)^n = 1 + \sum_{j=1}^{\infty} \frac{n(n-1)\cdots(n-j+1)}{j!} z^j$$

which is easily obtained from the first form if $z = y/x$. The series **converges** if $|z| < 1$ and **diverges** if $|z| > 1$.

SERIES, COMPARISON. The **convergence** of an infinite series may be established if, from a certain point onward, it may be shown that each term is less than or equal to the corresponding term of another series already known to be convergent. Similarly, if each term of a certain series is equal to or greater than the corresponding term of a series known to be **divergent** the unknown series is divergent. The comparison series is the known series used for test purposes.

SERIES CONNECTION. Network elements are said to be series-connected if they carry a common current.

SERIES ELEMENTS. (1) Two-terminal elements are connected in series when they form a path between two **nodes** of a **network** such that only elements of this path, and no other elements, terminate at intermediate nodes along the path. (2) Two-terminal elements are connected in series when any **mesh** including one must include the others.

SERIES-FED VERTICAL ANTENNA. See **antenna, series-fed vertical.**

SERIES, GEOMETRIC. A series whose terms form a **geometric progression.** If written as $a(1 + r + r^2 + r^3 + \cdots)$ its sum to n terms is

$$\frac{a(1 - r^n)}{(1 - r)}.$$

When $r < 1$, the infinite series **converges** and its sum is $a/(1 - r)$. The series **diverges** for other values of r.

SERIES, HARMONIC. A sum of terms which form a **harmonic progression.** There is no general method of finding the sum. It is usually done by taking the reciprocal series and solving the resulting arithmetic series. (See **series, arithmetic.**) If the series is

$$\sum_{n=1}^{\infty} 1/nr,$$

with r real, it converges for $r > 1$, but diverges for $r \leq 1$.

SERIES IN LINE SPECTRA. The spectra of many atoms having one, two, or three electrons in the outer shell (except H, He^+, $Li^{++} \cdots$) consist of a number of overlapping series each of which is Balmer-like with a characteristic formula of the type

$$\nu = \frac{R}{(a + c_1)} - \frac{R}{(n + c_2)}$$

where a, c_1 and c_2 are constants characteristic of the atom and the series, R is the **Rydberg constant** for the atom and n is a series of integers, $n > a$. The series in which the total azimuthal quantum number changes from 0 to 1 ($S \rightarrow P$) is called the "Sharp" series; from 1 to 0 ($P \rightarrow S$) is called the "Principal" series; from 2 to 1 ($D \rightarrow P$) is called the "Diffuse" series; from 3 to 2 ($F \rightarrow D$) is called the "Fundamental" series. Note that it is from the names of these series that the notation L = 0, S; L = 1, P; L = 2, D; L = 3, F arose.

SERIES INTEGRATION. The **integrand** of a definite or indefinite **integral** is expanded as an **infinite series** and the integration performed term by term. More commonly applied to the case of a **differential equation** where the solution is assumed to be

$$y = \sum_{n=0}^{\infty} A_n x^n.$$

This series is then substituted in the differential equation and the coefficients A_n are determined so that the equation is satisfied. (See also **indicial equation; recursion formula.**)

SERIES, OSCILLATING. A **series** which is not **convergent** but which is **bounded.** A simple example is $S_n = 1 - 1 + 1 - 1 + \cdots + (-1)^{n-1}$, for its sum is either zero or unity when n is taken as even or odd.

SERIES, POWER. An expression of the form $\Sigma a_k x^k$ where x is a variable and the numbers a_k are coefficients. There may be a finite or infinite number of terms in the sum.

SERIES RESONANCE. Resonance exists in a **series circuit** when the frequency of the impressed current or voltage is such that the **impedance** is real, i.e., purely resistive; the inductive and capacitative components of reactance cancelling one another.

SERIES, REVERSION OF. A given power series

$$y = a_0 + a_1 x + a_2 x^2 + \cdots$$

may be reverted to give an explicit representation of x as a function of y. The result is

$$x = z + c_1 z^2 + c_2 z^3 + \cdots$$

where $z = (y - a_0)/a_1$; $c_1 = -a_2/a_1$; $c_2 = -a_3/a_1 + 2(a_2/a_1)^2$; $c_3 = -a_4/a_1 + 5a_2a_3/a_1^2 - 5(a_2/a_1)^3$; $\cdots$.

Also called **inversion** of the series.

SERIES-TEE JUNCTION. See **junction, series-tee.**

SERIES TWO-TERMINAL PAIR NETWORKS. Two-terminal pair **networks** are connected in series at the input or at the output terminals when their respective input or output terminals are in series.

SERRATED PULSE. See **pulse, serrated.**

SERVICE AREA. The service resulting from an assigned **effective radiated power** and **antenna height** above the average terrain.

SERVICE BAND. A band of frequencies allocated to a given class of radio service.

SERVO. A combination of devices for controlling a source of power in which the output (or some function thereof) is fed back and compared to some reference at the input, the difference of this comparison being used to effect the desired control.

SERVOMECHANISM. A **servo** used to control a mechanical function.

SESSILE DROP METHOD. See **surface tension, methods of measurement.**

SET. A collection of numbers or symbols considered as a whole. For example, the set of all prime numbers or the set of all matrices with determinant equal to unity. Geometrically, the symbols in a set determine a **domain.**

SET, PERMANENT. When a solid has been strained beyond the **elastic limit** and the deforming stress is completely removed, in general the strain does not decrease ultimately to zero but to some non-vanishing value, known as a permanent set.

SET POINT. The position to which control-point-setting mechanism is set in an **automatic controller,** translated into units of the **controlled variable.**

SETTLING. The separation of suspended solid particles from a liquid by the action of gravity or other force.

SETTLING, HINDERED. Any method for the application of forces to particles undergoing **settling,** which yields better or more rapid classification by size than can be obtained by free settling. For example, such forces may be applied by flow of fluids, by vibration, etc.

SETUP. In television, the ratio between reference **black level** and reference **white level,** both measured from **blanking level.** It is usually expressed in per cent.

SG. Symbol frequently used to indicate the **screen grid** of a vacuum tube.

SHADE. A mixture of a color with black.

SHADING. (1) A method of controlling the **directivity pattern** of a **transducer** through control of the distribution of phase and amplitude of the transducer action over the active face. (2) In television, the process of compensating for the spurious signal generated in a **camera tube** during the trace intervals. (See **interval, trace; circuit, shading.**)

SHADOW EFFECT (U.H.F.). The reduction in signal strength due to some topographical feature in the line-of-sight path between the point of transmission and reception. (Cf. **shadow factor.**)

SHADOW FACTOR. The ratio of the **electric field strength** which would result from **propagation** over a sphere to that which would result from propagation over a plane, other factors being the same.

SHADOW ZONE. A region, usually in the atmosphere or under water, in which **ray acoustics** predicts zero penetration of sound rays.

SHANNON FORMULA. A theorem in information theory which states that a method of coding exists whereby C binary digits per second may be transmitted with arbitrarily small frequency of error where C is given by

$$C = B \log_2 \left(1 + \frac{S}{N}\right)$$

and no higher rate can be transmitted; B is the bandwidth, and S/N is the **signal-to-noise ratio.**

SHAPE FACTOR. See **Coddington shape and position factors.**

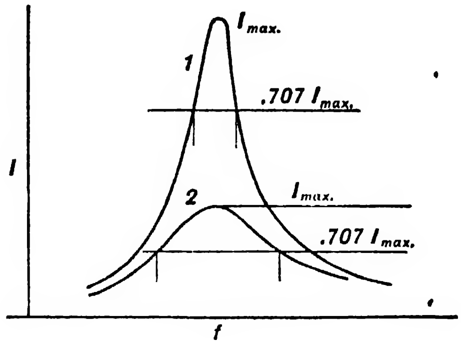
SHAPED - BEAM ANTENNA (PHASE-SHAPED). See **antenna, shaped-beam (phase-shaped).**

SHAPING NETWORK. An equalizing network. (See **network, equalizing.**)

SHARP SERIES. See **series in line spectra.**

SHARPNESS OF RESONANCE. Since resonant circuits give a response which varies with frequency, reaching a maximum at the resonance frequency and dropping on either side, it is convenient to have some means of comparing different circuits. The usual purpose of such circuits is to select certain frequencies in preference to others so the common method

of defining the sharpness of resonance is to specify the **frequency band** in which the response will exceed an arbitrary value. This arbitrary value is often taken as 70.7% of the maximum as this is the point where the power is half the value at **resonance.** The narrower the frequency band between these two points the sharper the **resonance**, thus in the figure



the circuit having the response curve 1 has much sharper resonance than that of curve 2. The frequency difference between these two half-power points is approximately equal to the resonance frequency divided by **Q**(**Q** > 10).

SHEAR. Any stress which displaces a plane of a solid body parallel to itself, relative to other parallel planes within the body, is known as a shearing stress. The magnitude of the shearing stress is the force per unit area of the plane. The shear strain is the ratio of the displacement of any plane, relative to a second plane, to the distance between planes; i.e., it is (the tangent of) the angle through which a line perpendicular to the planes is rotated by the shear.

SHEAR MODULUS OR RIGIDITY. In the case of a homogeneous isotropic elastic medium, the ratio of the shear **stress** to the shear **strain.** The rigidity of such a medium is $E/2(1 + \sigma)$, where E is the **Young modulus** and σ is the **Poisson ratio.**

SHEAR STRENGTH OF SINGLE CRYSTALS. According to classical theory, the shear strength of a perfect single crystal should be of the order of its **shear modulus.** This value is larger by a factor of the order of 10^5 than that observed in some cases. It is supposed that actually **slip** occurs by the movement of **dislocations** along the **glide planes.**

SHEAR WAVE. See **wave, shear.**

SHEARED BOUNDARY METHOD (FOR TRANSPORT NUMBER). An experimental scheme for producing an initial sharp boundary for use in the **moving boundary method.**

SHEATH. (1) A space-charge region in a **gas discharge**, due to an excess of either positive or negative charges. (2) The conducting walls of a uniconductor waveguide. (See **waveguide, uniconductor.**)

SHEATH-RESHAPING CONVERTER. A device which changes the mode of propagation in a **waveguide** by shaping the walls of the waveguide and/or by employing **sheet gratings** in the waveguide.

SHED. A unit of nuclear cross section equal to 10^{-24} **barn** or 10^{-48} square centimeter.

SHEET GRATING. Metal fins, usually at least a guide-wavelength long, placed longitudinally inside a **waveguide** to suppress undesirable **modes of propagation.**

SHELL MODEL OF NUCLEUS. (1) A nuclear model in which shell structure is postulated. (2) A nuclear model in which shell structure is a consequence of the postulates. Hence, usually, a synonym for independent particle model of nucleus. (See **shell structure of nucleus.**)

SHELL STRUCTURE OF NUCLEUS. The arrangement of the quantum states of nucleons of a given kind in a nucleus in groups of approximately the same energy. Each such group is called a shell, and the number of nucleons in each shell is limited by the **Pauli exclusion principle.** A closed shell is one containing the maximum number. A nucleus having all of its nucleons of either or both kinds in closed shells possesses greater than average stability. (See **independent particle model of nucleus; magic numbers.**)

SHF. Abbreviation for superhigh-frequency, the 3,000 to 30,000 megacycle band.

SHIELD. Any material used to reduce the amount of radiation reaching one region of space from another region of space.

SHIELD-GRID THYRATRON. See **thyratron, shield-grid.**

SHIELDED PAIR. A two-wire **transmission line** surrounded by a metallic **sheath.**

SHIELDED TRANSMISSION LINE. See **transmission line, shielded.**

SHIELDING. (1) In nuclear reactor terminology, the reduction of the amount of radiation reaching one region of space from another, as effected by a **shield,** or other device. (2) In many circuits, particularly in the fields of communication and electronics where the currents and voltages are often very small it is necessary to protect from external disturbances. This may be largely accomplished by shielding. Disturbing voltages may be induced in a circuit or part of a circuit by electrostatic or electromagnetic (or both) induction. The first is relatively easy to shield against since it is only necessary to surround the circuit with a conducting surface which is grounded This effectively prevents the electrostatic lines of force from reaching the circuit and thus inducing voltages in it. To shield from electromagnetic effects the magnetic lines of force must be prevented from linking the circuit Since there are no effective magnetic insulators and no perfect conductors this is difficult to do. Fortunately, the number of lines of force which do get to the circuit may be reduced to a small value which will usually not cause trouble At low frequencies (including the audio range) this is accomplished by surrounding the circuit by a material having high magnetic **permeability,** the higher the permeability the more perfect the shielding At radio frequencies the effective permeabilities of all magnetic materials approach unity At these frequencies the eddy currents induced in the shield serve to protect the circuit As a consequence, the better the conductivity of the shielding the better its protection, aluminum and copper being the materials ordinarily used

SHIELDING RATIO. The ratio of the field in a region of interest, with a **shield** in place, to the field in that region with the shield removed.

SHIELDING THEORY. (1) At **radio frequencies,** the effect of a shield can be computed, for idealized cases, in terms of the reflection of traveling waves at a discontinuity presented by the shield, and by the attenuation of the transmitted portion of the wave. (2) At very low frequencies, the effects of a shield can be approximated by their static behavior, i.e., the shielding can be thought of as due to **induced charges and magnetic moments** which tend to neutralize the field.

SHIFT. (1) In computer terminology, displacement of an ordered set of characters one or more columns to the right or left In the case in which the characters are the digits of a number, in a fixed-point digital computer, a shift is ordinarily equivalent to multiplication by a power of the radix. (2) A **shift of a spectral line.** (See also **Doppler effect; red shift.**)

SHIFT OF SPECTRAL LINE. A small displacement in the position of a spectral line that is caused by a corresponding change in frequency which is due, in turn, to one or more of a variety of causes, such as the **Doppler effect,** etc.

SHOCK EXCITATION. See **excitation, shock.**

SHOCK MOTION. In a mechanical system, transient motion which is characterized by suddenness and by significant relative displacements.

SHOCK WAVE. A wave in which an abrupt, finite change takes place in pressure and particle velocity. (See **velocity, particle.**) A shock wave can also be defined as a finite amplitude sound wave. Shock waves may be propagated at speeds appreciably greater than the **velocity of sound.**

SHORE EFFECT. The change in the characteristics of an electromagnetic wave as it passes along a land-sea boundary, due to a difference in the **propagation** characteristics of the two regions. A source of error in radio **direction-finders.**

SHORE SCALE OF HARDNESS. See **hardness scale, Shore.**

SHORT-CIRCUIT. An electrical circuit is considered to be shorted when the terminals are connected directly together with only the **impedance** of the short connecting leads between them, thus for all practical purposes there is no **resistance** between them, hence no voltage can exist between them. While shorting a circuit which does not contain and is not connected to any source of voltage will produce no harmful effects, shorting a set of terminals across which a voltage normally

exists will produce in many instances disastrous current flows.

SHORT-CIRCUIT DRIVING-POINT ADMITTANCE (OF THE *j*TH TERMINAL NETWORK). The **driving-point admittance** between that terminal and the reference terminal when all other terminals have zero alternating components of voltage with respect to the reference point.

SHORT-CIRCUIT FEEDBACK ADMITTANCE (OF AN ELECTRON-TUBE TRANSDUCER). The **short-circuit transfer admittance** from the physically available output terminals to the physically available input terminals of a specified socket, associated filters, and tube.

SHORT-CIRCUIT FORWARD ADMITTANCE (OF AN ELECTRON-TUBE TRANSDUCER). The **short-circuit transfer admittance** from the physically available input terminals to the physically available output terminals of a specified socket, associated filters, and tube.

SHORT-CIRCUIT INPUT ADMITTANCE (OF AN ELECTRON-TUBE TRANSDUCER). The **short-circuit driving-point admittance** at the physically available input terminals of a specified socket, associated filters, and electron tube.

SHORT-CIRCUIT INPUT CAPACITANCE (OF AN *n*-TERMINAL ELECTRON TUBE). The effective capacitance determined from the **short-circuit input admittance.**

SHORT-CIRCUIT OUTPUT ADMITTANCE (OF AN ELECTRON-TUBE TRANSDUCER). The **short-circuit driving-point admittance** at the physically available output terminals of a specified socket, associated filters and tube.

SHORT-CIRCUIT OUTPUT CAPACITANCE (OF AN *n*-TERMINAL ELECTRON TUBE). The effective capacitance determined from the **short-circuit output admittance.**

SHORT-CIRCUIT TRANSFER ADMITTANCE (FROM THE *j*TH TERMINAL TO THE *l*TH TERMINAL OF AN *n*-TERMINAL NETWORK). The transfer admittance from terminal j to terminal l when all terminals except j have zero complex alternating components of voltage with respect to the reference point.

SHORT-CIRCUIT TRANSFER CAPACITANCE (OF AN ELECTRON TUBE). The effective capacitance determined from the **short-circuit transfer admittance.**

SHORT-PATH PRINCIPLE. See **Hittorf principle.**

SHORT-RANGE FORCE. A force between two particles which is essentially ineffective when the interparticle separation exceeds a certain distance; usually applied to nuclear forces which have a range of several times 10^{-13} cm.

SHORT-RANGE ORDER. The type of **order** in which the probability of a given type of atom having neighbors of a given type (for example, that an A atom is surrounded by B atoms) is greater than would be expected on a purely random basis. There is thus a tendency to form small ordered domains, but these do not link together at long distances. Short-range order occurs in **binary alloys** above the **order-disorder transition** temperature, and is measured by the parameter,

$$\sigma = \frac{q - q(rand)}{q(max) - q(rand)}$$

where q is the fraction of the total number of nearest-neighbor bonds in the solid between unlike atoms, $q(max)$ is the maximum possible value of q for the given ratio of constituents, and $q(rand)$ is the value of q for an entirely random arrangement.

Short range order is characteristic of liquids and disordered solids, in contrast to the **long range order** found in crystalline solids.

SHORT-WAVE CONVERTER. A device consisting of a **heterodyne detector** or **mixer** and an appropriate local **oscillator.** The desired short-wave frequency is converted to a frequency which is within the standard broadcast band.

SHOT EFFECT. A troublesome phenomenon which gives rise to a sputtering or popping noise in **radio** and **amplifier** apparatus. It was called *Schroteffekt* (small shot effect) by Schottky, who first explained it as due to variations in the number of thermions per sec emitted from the tube filament. This varia-

tion seems to be merely a statistical one, like the variations in the forces acting on particles exhibiting the **Brownian movement.** Its magnitude depends upon several factors, among which is the influence of the space charge (distribution of electrons) within the tube. A somewhat similar effect, produced by random variations in the velocities of the electrons, and depending upon the temperature of the filament, is manifest in what is called thermal noise, and is superposed on the shot noise. There is also a shot effect in the emission of photoelectrons, observable in the operation of **photoelectric cells.**

SHOWER. (1) Precipitation characterized by sudden starting and stopping, and by rapid changes in intensity. Shower rain is usually associated with **cumulonimbus**-type clouds and instability in the air. (2) For use of the term shower as applied to charged particles or photons, see **shower, cascade; shower, extensive; cosmic-ray shower,** etc.

SHOWER, CASCADE. A type of **cosmic-ray shower** that is initiated when a high-energy electron, in its passage through matter, produces one or more photons of energies comparable with its own. These photons then convert into electrons and positrons by the process of **pair production.** The secondary electrons in turn produce the same effects as the primary, and thus the number of particles increases along the way. The cascade shower of electrons and positrons builds up until the level of energy is so low that photon emission and pair production can no longer occur.

SHOWER, EXTENSIVE. A shower of many **cosmic-ray** particles extending over a fairly large area, on the order of 100 meters in diameter. Such showers presumably are initiated high in the atmosphere by a single cosmic ray, having energy as great as 10^{15}–10^{17} ev.

SHOWER, PENETRATING. A **cosmic-ray shower** in which some or all of the constituent particles can penetrate absorbing material further than is possible for electromagnetic radiation, usually penetrating 15–20 cm of lead. The particles are mainly μ mesons. (See **shower, cascade.**)

SHOWER THEORY. See **cascade theory.**

SHOWER UNIT (COSMIC RAYS). The mean path length required for the reduction, by the factor ½, of the energy of relativistic charged particles as they pass through matter. Such particles lose their energy mostly by radiation (see **bremsstrahlung**). The shower unit s is related to the **radiation length** l by the equation:

$$s = l \ln 2 = 0.693l.$$

SHUNT. An electrical bypath so arranged that an **electric current** divides and flows partially through the shunt, and partially through the equipment that is shunted. Shunts are used extensively to reduce the sensitivity and to lower the effective resistance of **galvanometers.** In this connection see **ammeter;** and **shunt, Ayrton.**

SHUNT, AYRTON. A device used in connection with a **galvanometer** to provide variable current **sensitivity (4).** The galvanometer is connected across a resistance R, approximately equal to that required for optimal damping (cf. **damping, optimal**). The input terminals are two taps on R, the resistance between them being R/n, where n is usually a positive power of ten.

SHUNT EXCITED. This is a method of exciting tower **antennae** which are not insulated from the **ground** at the base. The feeder is connected to a point about ⅕ of the way up the antenna, the exact location depending on many factors and usually involving some cut-and-try. For proper operation the feeder should slope up to the point of attachment from a point some distance from the base of the antenna, the slope being adjusted experimentally. The term is also applied to the method employed in providing field current for d-c **dynamos.** A shunt-excited machine is one in which the field windings are connected across the **armature** terminals.

SHUNT-FED VERTICAL ANTENNA. See **antenna, shunt-fed vertical.**

SHUNT RECTIFIER. Synonym for **free-wheeling rectifier.**

SHUNT TEE JUNCTION. See **junction, shunt tee.**

SIDEBAND(S). (1) The frequency bands on both sides of the **carrier frequency within** which fall the frequencies of the **wave pro-**

duced by the process of **modulation.** (2) The wave components lying within such bands. In the process of **amplitude modulation** with a sine-wave carrier, the upper sideband includes the sum (carrier plus modulating) frequencies, the lower sideband includes the difference (carrier minus modulating) frequencies.

SIDEBAND ATTENUATION. See **attenuation, sideband.**

SIDEBAND, VESTIGIAL. The transmitted portion of the **sideband** which has been largely suppressed by a **transducer** having a gradual **cutoff** in the neighborhood of the carrier frequency, the other sideband being transmitted without much suppression

SIDE CIRCUIT. See **phantom circuit.**

SIDE FREQUENCY. See **frequency, side.**

SIDE THRUST. In disc recording, the radial component of force on a **pickup arm** caused by the stylus drag.

SIDE-THRUST EFFECT. The result of the force developed on a charged particle moving in a magnetic field. If the velocity and magnetic field are perpendicular to each other, the force produced is mutually perpendicular to both This is the well-known "motor action"

SIEGBAHN UNIT (X-UNIT). A length of 10^{-11} cm, widely used in expressing the wavelength of x-rays

SIEMENS. A trade name for a form of **syncro.**

SIEMENS COUNTERCURRENT HEAT EXCHANGER. A device, in its simplest form consisting of two concentric tubes, by which the heat content of a fluid moving in one tube can be transferred to the fluid moving in the other tube in opposite direction.

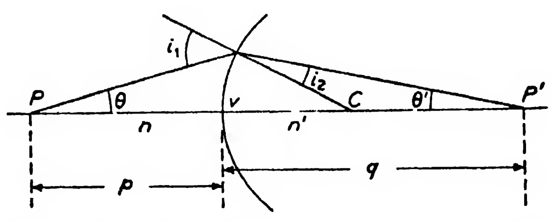
SIF. In television, an abbreviation for sound intermediate frequency.

SIGMA. (1) Mathematical summation (Σ). (2) Surface tension (σ, but γ is more commonly used). (3) Millisecond (σ). (4) Cross section (σ), total cross section (σ_s), cross section for atom in a mixture (σ_t). (5) Electric conductivity (σ). (6) Collision diameter of molecule (σ) (7) Dispersion (σ). (8) Thomson coefficient (σ). (9) Wave number (σ). (10) Stefan-Boltzmann constant (σ). (11) Exposure (Σ). (12) Surface charge density (σ). (13) Mass per unit area (σ). (14) Projection of S (the resultant angular momentum of electron spins) on the molecular axis (Hund case a) (Σ) (15) Electronic state of molecule having $\Lambda = 0$ (Σ). (16) Σ-state for which the electronic wave-functions are symmetric and antisymmetric, respectively, with respect to any plane containing the molecular axis (Σ^+, Σ^-).

SIGMA PILE (NUCLEAR REACTOR). An assembly of a moderating material containing a neutron source, used in the study of the neutron properties of the material.

SIGN CONVENTION (LENS AND MIRROR). Since every distance involved in lens computations must be measured from some origin, a convention of signs should be adopted to insure consistency in the derivation and use of formulae. Unfortunately this has not been done by all authors. The following probably has the largest following: (1) Draw all figures with the light incident on the reflecting or refracting surface from the left. (2) Consider the object distance $p = PV$ positive when P is at the left of the vertex. (3) Consider the image distance $q = VP'$ positive when P' is at the right of the vertex (4) Consider the radius of curvature $R = CV$ positive when the center of curvature lies to the right of the vertex (5) Consider the slope angles positive when the axis must be rotated counterclockwise through less than $\pi/2$ to bring it into coincidence with the ray. (6) Consider angles of incidence and refraction positive when the **radius of curvature** must be rotated counterclockwise through less than $\pi/2$ to bring it into coincidence with the ray. (7) Consider distances normal to the axis positive when measured upward.

In the following diagram only θ' is negative.



When the convention is followed, the simple lens formula takes the form

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right).$$

SIGN, DIGIT. A character used to designate the algebraic sign of a number.

SIGNAL. (1) An independent input variable. (2) A visual, audible, or other indication used to convey information. (3) The intelligence, message, or effect to be conveyed over a communication system. (4) A signal wave.

SIGNAL, BLANKING. See **blanking signal.**

SIGNAL(S), DRIVING. In television, signals that time the **scanning** at the **pickup point.** Two kinds of driving signals are usually available from a central **sync generator.** One is composed of **pulses** at line frequency and the other is composed of **pulses** at field frequency.

SIGNAL ELECTRODE (OF A CAMERA TUBE). See **electrode, signal (of a camera tube).**

SIGNAL GENERATOR. A wide-range radio-frequency **oscillator,** usually with provisions for **modulation,** used for test purposes.

SIGNAL, INPUT. The power fed into the input of a device or circuit.

SIGNAL LEVEL. At any point in a transmission system, the difference of the measure of the signal at that point from the measure of an arbitrarily-specified signal chosen as a reference. In audio techniques, the measures of the signal are often expressed in **decibels,** thus their difference is conveniently expressed as a ratio.

SIGNAL, OUTPUT. The power delivered by a device or circuit.

SIGNAL POWER, AVAILABLE. The maximum signal power that can be drawn from the output terminals of a **network** by a **load** whose impedance is the complex conjugate of the impedance seen when looking back into the network.

SIGNAL-SHAPING NETWORK. An **equalizer network.**

SIGNAL-TO-NOISE MERIT. See **signal-to-noise ratio.**

SIGNAL-TO-NOISE RATIO. The ratio of the value of the signal to that of the noise. This ratio is usually in terms of peak values in the case of impulse noise (see **noise, impulse**) and in terms of the root-mean-square values in the case of the random noise (see **noise, random**). Where there is a possibility of ambiguity, suitable definitions of the signal and noise should be associated with the term; as, for example: peak-signal to peak-noise ratio; root-mean-square signal to root-mean-square noise ratio; peak-to-peak signal to peak-to-peak noise ratio, etc. This ratio is often expressed in decibels. This ratio may be a function of the **bandwidth** of the transmission system.

SIGNAL-TO-NOISE RATIO, AVAILABLE. The ratio of the available signal power to the available noise power. (See **signal-to-noise ratio.**)

SIGNAL, STANDARD TELEVISION. A **signal** which conforms to the television transmission standards.

SIGNAL(S), SYNCHRONIZING. See **synchronizing, radio; synchronizing, television; synchronizing signal.**

SIGNAL WINDINGS. Of a **saturable reactor,** those control windings to which the independent variables (signals) are applied.

SILENT PERIOD. See **international silent period.**

SILICON. Nonmetallic element. Symbol Si. Atomic number 14.

SILSBEE RULE. A long circular wire of radius a cannot carry a supercurrent greater than $\frac{1}{2}aH_c$, where H_c is the **critical field** of the material. Evidently the magnetic field of the current itself then destroys the **superconductivity.**

SILVER. Metallic element. Symbol Ag (argentum). Atomic number 47.

SILVERSTAT. The trade name for a control device with a number of contacts arranged so that the number of contacts closed is proportional to a control force The contacts can, as an example, short out resistances in series with a generator field, causing the output voltage to vary as a direct function of control force. The control force may be developed by an unbalanced gyro, an electromagnet, etc.

SILVER THAW. After a period of cold weather and below-freezing temperature a mass of warm air passing over the region will cause frost or glaze to form on objects that are still at a low temperature. This condition is known as a silver thaw, and usually lasts only a few hours, as the warm air soon warms all exposed objects above 32°F.

SIMPLE HARMONIC MOTION. See **motion, simple harmonic; oscillator, harmonic; oscillator, linear;** and **harmonic motion.**

SIMPLE SOUND SOURCE. See **sound source, simple.**

SINGLE-SURFACE EQUATION, PARAXIAL. See **paraxial single-surface equation.**

SIMPLE TONE (PURE TONE). See **tone, simple.**

SIMPLEX OPERATION OF A RADIO SYSTEM. A method of operation in which communication between two stations takes place in one direction at a time This includes ordinary transmit-receive operation, press-to-talk operation, voice-operated carrier, and other forms of manual or automatic switching from transmit to receive.

SIMPLEXED CIRCUIT. A circuit used to transmit two signals simultaneously. (See **phantom circuit.**)

SIMPSON ONE-THIRD RULE. A numerical **quadrature** formula

$$\int_a^b f(x)dx = \frac{h}{3}[y_0 + 4(y_1 + y_3 + \cdots + y_{n-1}) + 2(y_2 + y_4 + \cdots + y_{n-2}) + y_n]$$

where h is the interval between equally spaced values of the independent variable x, and y_j is the value of $f(x)$ at the beginning of the $(j + 1)$st interval.

SIMULATION. The representation of physical systems by **computers** and associated equipment.

SIMULTANEITY. Two **events** are simultaneous relative to an observer when they occur at the same time according to a clock fixed relative to him, even although for an observer moving relative to the first they will not be simultaneous if they occur at different points.

SIN POTENTIOMETER. See **potentiometer, sin.**

SINE WAVE. A wave which can be expressed as the sine of a linear function of time, or space, or both.

SINGING. An undesired self-sustained **oscillation** existing in a **transmission system.**

SINGING POINT. In a closed **transmission system,** that adjustment of **gain** or **phase,** or both, at which **singing** will start.

SINGLE - ADDRESS (INSTRUCTION) CODE. An **instruction** in general consists of a coded representation of the operation to be performed and of one or more **addresses** of words in storage. The instructions of a single-address code contain only one address.

SINGLE CRYSTAL. A macroscopic specimen of a solid in which all parts have the same crystallographic orientation.

SINGLE-ELECTRODE POTENTIAL. See **electrode potential, single.**

SINGLE-ENDED AMPLIFIER. See **amplifier, single-ended.**

SINGLE OPERATION. See **simplex operation.**

"SINGLE PARITY" CHECK. An error-detecting code for a binary system.

SINGLE PARTICLE MODEL OF NUCLEUS. A synonym for **independent particle model of nucleus.**

SINGLE-SIDEBAND MODULATION OR SS. See **modulation, single-sideband or SS.**

SINGLE-SIDEBAND TRANSMISSION. See **transmission, single-sideband.**

SINGLE-SIDEBAND TRANSMITTER. See **transmitter, single-sideband.**

SINGLE-SIGNAL RECEPTION. Reception achieved with a **receiver** of sufficiently high selectivity to eliminate all but the desired signal.

SINGLE-TONE KEYING. See **keying, single-tone.**

SINGULAR. Referring to unusual or peculiar behavior of a function. Thus, a **singular matrix** is one for which the determinant vanishes. An **integral equation** with infinite

limits of integration or an infinite **kernel** is singular. Coefficients of a linear **differential equation** become infinite at a singular point and **singular solutions** of them may also exist. If the slope of a curve becomes infinite the point is called a **singular point** for the **curve.**

SINGULAR POINT, ELEMENTARY. At a regular singular point of a linear **differential equation** the difference between the two **exponents** of the **indicial equation** is arbitrary, except that it cannot be zero or integral. If this difference equals ½, the singularity is **elementary.**

SINGULAR POINT, ESSENTIAL. A singularity of a function of the complex variable which is not a **pole** or a **branch point.** It is actually a pole of infinite order. A simple example is

$$w(z) = \sin 1/z = \frac{1}{z} - \frac{1}{3!z^3} + \frac{1}{5!z^5} - \frac{1}{7!z^7} \pm \cdots$$

and it is seen that no finite values of the exponent n in $z^n w(z)$ will remove the singular point of this function at $z = 0$. (See also **Laurent series.**)

SINGULAR POINT FOR COMPLEX VARIABLE. A particular value of the **complex variable** z for which a function of that variable $f(z)$ is not **analytic.** Hence any point which is not an **ordinary point.** Singular points or singularities are classified as: (1) **poles** or unessential singularities, (2) essential singularities (see **singular point, essential**) or poles of infinite order; (3) **branch points** caused by the fact that the function is not single-valued.

SINGULAR POINT FOR PLANE CURVE. Any point on a given curve for which the **derivative** becomes indeterminate Any other point is an **ordinary point.** Let the equation of the curve be $f(x,y) = 0$, then a singular point occurs at a point (x_0,y_0), provided

$$\partial f/\partial x = 0 \quad \text{and} \quad \partial f/\partial y = 0$$

at that point, for the derivative is

$$dy/dx = -\partial f/\partial x/\partial f/\partial y.$$

If there are two, three, etc., tangents to the curve the singular point is a double point, triple point, etc. Functions of the second derivative are used to classify the singular point as a **node, point of osculation, cusp** of the first or second kind, **conjugated** or **isolated point, end point, salient point.**

SINGULAR POINT, IRREGULAR. A singular point of a linear **differential equation** which is not a regular singular point (see **singular point, regular**). In the case of a second-order differential equation, the **indicial equation** at an irregular singular point is of first degree or less and there is only one series solution there or none. An irregular singular point of a differential equation arises from the **confluence** of two or more regular singular points.

SINGULAR POINT, NON-ESSENTIAL. A **pole** of finite order.

SINGULAR POINT, REGULAR. The point $z = z_0$ is a regular singular point of the second-order linear **differential equation**

$$y'' + \frac{P(z)}{z - z_0} y' + \frac{Q(z)}{(z - z_0)^2} y = 0$$

provided: (1) z_0 is not an **ordinary point;** (2) both $P(z)$ and $Q(z)$ are **analytic** functions at $z = z_0$. If these conditions are not met, the singularity is irregular. This classification of singular points may be extended to linear differential equations of any order.

SINGULAR POINT, TRANSCENDENTAL. If a curve is represented by a **transcendental equation,** it may have a singularity, called an **end point,** where the curve terminates suddenly due to a **discontinuity;** a **salient point,** where the two **branches** of the curve end because of a discontinuity in the derivative. Examples are: $y = \ln x$, an end point at the origin; $y = x \tan^{-1} 1/x$, a salient point at the origin.

SINGULAR SOLUTION. A **solution** to a **differential equation** which is not a special case of the **general solution** hence not obtainable from the general solution by assigning a value to its parameters. (See **Clairaut equation.**)

SINIMAX. A nickel-iron-silicon, medium permeability magnetic alloy.

SIREN. Usually, a revolving disc perforated with a ring of equally spaced holes which interrupt a tube placed close to one side of the disc. The fundamental frequency of the successive puffs of air issuing through the holes

is equal to the product of the number of holes and the number of revolutions per second of the disc. High sound intensities can be obtained.

SIX-VECTOR. An antisymmetrical tensor which in virtue of the conditions $T_{\mu\nu} = -T_{\nu\mu}$ has, for $\mu,\nu = 1 \cdots 4$, only six independent components. The electromagnetic field components $E_xE_yE_z$, $B_xB_yB_z$ may be represented as the components of a six-vector.

SKIASCOPE. An instrument for studying the optical **refraction** within the eye.

SKIATRON. A form of **cathode-ray tube** in which the opacity of the screen is varied as a function of beam intensity.

SKIN DEPTH. For a conductor carrying currents at a given frequency as a result of the **electromagnetic waves** acting upon its surface, the depth below the surface at which the current density has decreased one **neper** below the current density at the surface. Usually the skin depth is sufficiently small so that for ordinary configurations of good conductors, the value obtained for a plane wave falling on a plane surface is a good approximation. The skin depth is given by the relationship:

$$\delta = \frac{1}{\sqrt{\pi f \mu \sigma}}$$

where f is given in cycles per second, μ is given in henries per meter, and σ is given in mhos per meter.

SKIN EFFECT. The phenomenon wherein the depth of penetration of electric currents into a conductor decreases as the frequency of the current is increased. At very high frequencies the current flow is restricted to an extremely-thin, outer layer of the conductor. In this layer it presents essentially a "current sheet," which shields parts of the conductor away from the conducting surface, from the effects of external fields to the extent that there is little or no tendency for current to flow in those regions.

SKIN RESISTANCE. The skin resistance of a unit square is equal to $1/\sigma\delta$ where σ is the electrical conductivity of the conductor and where δ is the depth of penetration at the frequency of measurement. It is thus seen that the skin resistance is the same as the d-c resistance of a unit square and thickness δ. (See **skin depth.**)

SKIOGRAPH. An apparatus which measures the intensity of x-rays.

SKIP DISTANCE. As the frequency of a radio wave is increased the minimum angle of incidence at which the wave will be reflected from the **ionosphere** rather than pass on through becomes greater. This means that the higher the frequency the farther from the **transmitter** the reflected **sky wave** strikes the earth. This distance between the transmitter and the point closest to it at which the sky wave can be received is the skip distance. The **ground wave** is attenuated more rapidly the higher the frequency so that at high frequencies there may be a region in which the ground wave has become too weak for use and in which the sky wave cannot be received because of its skip. Above about 4 megacycles this effect becomes very noticeable, the dead region for higher frequencies running to a distance of a few hundred miles from the transmitter.

SKY CONDITION. The state of the sky is also known as the sky condition. In terms of tenths of sky covered, airways' observers in the U.S. recognize four sky conditions:

(1) Clear sky is less than 1/10 cover of clouds.

(2) Scattered clouds is 1/10 to 5/10 cover.

(3) Broken clouds is more than 5/10 but not more than 9/10 cover.

(4) Overcast is more than 9/10 cover.

International practice and observations made for **synoptic charts** in North America recognize 10 states of the sky. They are indicated by code numbers, as follows:

0	No clouds
1	Less than 1/10
2	1/10
3	2/10 to 3/10
4	4/10 to 6/10
5	7/10 to 8/10
6	9/10
7	More than 9/10 but with openings
8	10/10
9	Sky obscured by fog, dust, snow, etc.

SKY WAVE. See **ionospheric wave.**

SLATER METHOD. A method for treating the problem of the many-electron atom, involving antisymmetrical functions, which yield the relative values of **coulomb** and **exchange energy.** As in the Hartree method, the variational method is used to test the values for the total energy. *Phys. Rev.* **34,** 1293 (1929); **35,** 210 (1930).

SLEET. Frozen rain drops (or drizzle) which fall as particles of ice. (International usage defines sleet as a mixture of rain and snow.)

SLEEVE. The contact portion of a phone plug which is farthest from the tip It is also the largest in size, and is generally a part of the plug frame.

SLEEVE-DIPOLE ANTENNA. See **antenna, sleeve-dipole.**

SLICER. A **clipping limiter** or **amplitude gate.**

SLIDE-BACK VOLTMETER. See **voltmeter, slide-back.**

SLIDE WIRE. In electrical measurements, any **voltage divider** consisting of a single wire connected between two **nodes,** with a contact that may be moved along the wire. The wire is often arranged in a circle or a **helix.**

SLIDE-WIRE BRIDGE. See **bridge, Wheatstone.**

SLIP. (1) The process by which a crystal undergoes plastic deformation, as a result of which one atomic plane moves bodily over another. Slip is believed to occur through the movement of **dislocations.** The total deformation of a given crystal is the sum of many small lateral displacements in parallel crystallographic planes of a given family. Moreover each slip plane becomes more resistant to further deformation than the remaining potential slip planes. (2) A characteristic of the **induction motor;** namely, the percentage by which the rotor-speed falls below synchronous speed. The slip varies from practically zero at no-load, up to maximum at the stalling torque. (3) See **slip of a fluid along a surface.**

SLIP BANDS. Lines formed on the surface of plastically-deformed, **single crystals** defining planes in which **shear** displacement has taken place.

SLIP OF A FLUID ALONG A SURFACE. The slip of a fluid flowing past a surface may be defined as the difference between the velocity of the surface and the mean velocity of the fluid at a point just outside. Although very large velocity gradients frequently occur in the neighborhood of solid surfaces, many experiments have shown that the slip is extremely small for liquids and for gases under normal conditions. For gases, the slip velocity is of the order of the local velocity gradient multiplied by the mean free path, and it does become appreciable for very low densities or very high speeds of flow.

SLIP PLANE. An **atomic plane** of a crystal along which **slip** may be supposed to have taken place in order to create an **edge dislocation;** the latter moves freely along its slip plane.

SLIP RINGS. Conducting rings attached to a rotating part of an electrical machine to make connection through **brushes** with the stationary part of the circuit. They are used where it is not necessary to commutate the current being conducted. (See **commutation.**)

SLIT. The long narrow openings by which radiation enters or leaves certain **diffraction** or other optical instruments. Slits are often used as line sources of radiation or of particles, and combination of two or more slits are employed to achieve the **collimation of beams (1).**

SLIT, DOUBLE. Two long narrow parallel openings used in certain diffraction and interference experiments. (See Robertson, *Introduction to Optics,* 4th Ed , pages 148 and 221.)

SLIT, ENTRANCE. See **entrance slit.**

SLIT, EXIT. See **exit slit.**

SLOPE. In rectangular coordinates, the ratio of the change of the **ordinate** to the corresponding change of the **abscissa** of a point moving along a line. If a straight line is determined by the points (x_1,y_1) and (x_2,y_2) its **slope** $m = (y_2 - y_1)/(x_2 - x_1)$. If the line is not straight its slope is given by

$$\lim_{x_2 \to x_1} m = (dy/dx)_{x = x_1}.$$

SLOT, ANTENNA. See **antenna slot.**

SLOW MOTION OF SPHERE IN INCOMPRESSIBLE VISCOUS FLUID. Fluid motion at such low velocities (low **Reynolds numbers**) that pressure gradients and inertial forces are generally negligible compared with the viscous forces satisfies the equation

$$\nabla^2 \boldsymbol{\omega} = 0$$

where $\boldsymbol{\omega}$ is **vorticity.** If the flow is two-dimensional or axisymmetric, it is possible to set up a stream-function ψ which satisfies the equation

$$\nabla^4 \psi = 0$$

where ∇^4 is the square of the **Laplacian** operator ∇^2. **Stokes law** states that the resistance to motion under these conditions is given by

$$R = 6\pi\eta av$$

where η is the fluid viscosity, a is the radius of the sphere, v is the velocity of the sphere.

SLOW NEUTRONS. See **neutrons, slow.**

SLOWING DOWN. The loss of kinetic energy of a particle resulting from repeated collisions with atomic nuclei. Applied particularly to neutrons. (See **moderator.**)

SLOWING-DOWN AREA. (1) In an infinite homogeneous medium, one-sixth the mean square distance between the neutron source and the point where the neutron reaches a given energy. (2) In Fermi theory, the **age.**

SLOWING-DOWN DENSITY (NEUTRON). At a given energy and time, the number of neutrons per unit volume per unit time which are going from an energy greater than the given energy to an energy lower than the given energy.

SLOWING-DOWN LENGTH (NEUTRON). The square-root of the **slowing-down area.**

SLOWING-DOWN MODEL, CONTINUOUS. A treatment of the slowing-down process which replaces the step-wise decrease of energy due to collisions by a continuous curve.

SLOWING-DOWN POWER (NEUTRON). The average loss in natural logarithm of energy (average increase in **lethargy**) of a neutron per unit distance traveled by the neutron in the substance.

SLOWING OF CLOCKS. Effect predicted by special relativity theory (see **relativity theory, special**) that if in its **rest-frame** a clock ticks n times per second then from the point of view of an observer moving with velocity v relative to the clock it will appear to tick

$$n\left(1 - \frac{v^2}{c^2}\right)^{1/2}$$

times per second.

SLUG. A unit of mass in the f lbf s system of units, being the mass which is accelerated at 1 ft/s^2 by a force of one pound. It is equal to 32.174 lbm.

SLUG TUNER, COAXIAL-LINE. An impedance-matching technique which employs two quarter-wavelength dielectric beads or slugs inserted in the line Each slug acts as a quarter-wavelength line **transformer.** The position between the slugs is varied to achieve the desired tuning effect.

SLUG TUNING. A means for varying the frequency of a **resonant circuit** by introducing a slug of material into either the electric or magnetic fields or both.

SMALL-SIGNAL THEORY. The concept of using small excursions of current and voltage from their quiescent operating points in order that difficulties due to the non-linearities may be minimized.

SMEAR. Loss of television image definition due to lack of sufficiently high video-frequency response, or due to **smear ghosts.**

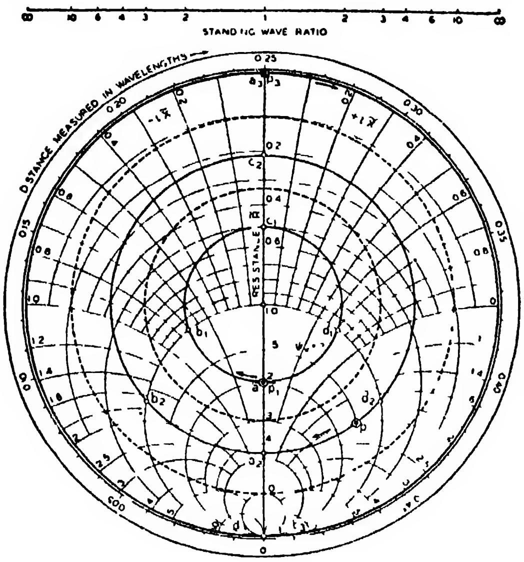
SMEAR GHOST. In television, ghost images which follow the desired image so closely that the overall effect is one of smearing.

SMEARER CIRCUIT. See **circuit, smearer.**

SMECTIC PHASE. One of the forms of the **mesomorphic state,** or the **"liquid crystals."** In the smectic phase, flow does not occur normally; the substance often forms drops which show a series of fine lines, especially on examination with polarized light. The liquid motion is more of a "gliding" than a flowing action, and x-ray diffraction patterns are obtained in one direction only.

SMITH DIAGRAM (CHART). A diagram with polar coordinates, developed to aid in the solution of transmission line and wave-

guide problems. It is composed of the following sets of lines: (1) Constant resistance circles. (2) Constant **reactance** circles. (3)



Smith diagram showing circles of constant standing wave ratio, each corresponding to a particular terminal impedance as follows (a) The terminal impedance (p_1) is $\tilde{Z}(l)$ 2 + i0 (b) The terminal impedance (p_2) is $\tilde{Z}(l) = 1.5 + i2$ (c) The terminal impedance (p_3) is $\tilde{Z}(l) = 0 + i0$ (By permission from "Principles and Applications of Waveguide Transmission" by Southworth, Copyright 1950, D. Van Nostrand Co., Inc.)

Circles of constant **standing wave ratio.** (4) Radius lines representing constant line-angle loci. The chart employs normalized quantities for maximum flexibility.

SMITH-HELMHOLTZ LAW. See **Lagrange theorem.**

SMOG. A mixture of smoke and fog.

SMOOTHING CHOKE. An **inductor** used in a circuit designed to decrease the **ripple** in a d-c power source.

SMPE. Abbreviation for Society of Motion Picture Engineers.

SNAP ACTION. In **magnetic amplifiers** with excessively large amounts of positive **feedback,** the abrupt jump in output current as a function of control current. Hysteresis is present so that the jump up does not occur at the same value of control current as the **jump down.** Other types of feedback systems also sometimes exhibit similar action.

SNELL LAW(S). (1) When light passes from one medium to another, the incident ray, the normal to the surface at the point of incidence, and the refracted ray are all in the same plane.

(2) The sine of the angle of incidence bears to the sine of the **angle of refraction** a ratio which is constant for the same two media, and depends only on the nature of those media.

$$n_1 \sin i_1 = n_2 \sin i_2,$$

where n_1 and n_2 are the indices of refraction of the first and second media, respectively.

For a medium (air) for which $n_1 = 1$ (nearly),

$$n_2 = \frac{\sin i_1}{\sin i_2}.$$

If $n_1 > n_2$, it is impossible to satisfy the Snell law, for $\sin i_1 > n_2/n_1$. **Total internal reflection** then occurs.

SNELL LAW APPLIED TO SOUND. Identical in form to the Snell law in optics. For nondissipative media, $\sin \theta_2/\sin \theta_1 = c_2/c_1$, where θ_1 is the angle of incidence, θ_2 the angle of refraction, c_1 the speed of sound in the incident medium and c_2 the speed of sound in the refracting medium.

SNOW. (1) Solid water in the form of branched hexagonal crystals sometimes mixed with simple ice crystals. (2) The colloquial term for the random pattern of white dots present on a television screen under a weak or zero signal condition. This pattern is due to **thermal-** and **shot-noise** sources within the receiver.

SNOW PELLETS. Whitish, opaque, usually round pellets with a structure something like snow. They are compressible and often burst when striking a hard surface. They are a shower type of **hydrometeor.**

SODIUM. Metallic element. Symbol Na (natrium). Atomic number 11.

SOFT PHOTOTUBE. See **gas phototube;** also **tube, soft.**

SOFTENING TEMPERATURE. A more or less definite physical constant of a substance that does not have a definite melting point, defined as the temperature at which viscous flow changes to plastic flow.

SOGASOID. A dispersed system of a solid in a gas.

SOL. A **colloidal solution** in which the system is apparently liquid. If water is the continuous phase the system is termed a hydrosol. The term sol is also applied to the dispersion medium of a colloidal solution.

SOL(S), PROTECTION OF. The protection of certain **lyophobic systems** against the coagulating effect of electrolytes by the addition of certain **lyophilic** sols. An example is the addition of large amounts of a gelatine sol to a gold sol. (See also **gold number.**) The amount of lyophilic sol necessary to protect the lyophobic sol depends on the charges carried by the sols. (See also **sols, sensitization of.**) When the charges on the two types are the same only protection is observed. When the charges are opposite, small amounts of the lyophilic sol tend to sensitize, and large amounts to stabilize the lyophobic sol.

SOL(S), SENSITIZATION OF. The coagulation of a **lyophobic sol** by the addition of a **lyophilic sol.** An example is the coagulation of certain gold sols by the addition of very small amounts of gelatine, e.g., 5×10^{-4} per cent gelatine for a 0.01 per cent gold sol. (See also **sols, protection of.**)

SOLAR CONSTANT OF RADIATION. The intensity of solar radiation in free space at the earth's mean solar distance. The constant is usually expressed in g cal cm^{-2} min^{-1}, and is equivalent to the amount of radiation incident in unit time on unit surface exposed perpendicularly to unimpeded radiation from the sun. Measurements on earth must be corrected for the effect of the atmosphere.

SOLAR RADIATION. The **radiation** from the sun comprises a very wide range of wavelengths from the long **infra-red** rays to the short **ultra-violet** rays, with a maximum intensity in the visible green at about 5000 **angstroms.** However, since the **air** strongly absorbs the wavelengths toward either end of the **spectrum,** the solar radiation received on the surface of the earth is confined, largely, to the visible and near infra-red regions, with a very small proportion of the ultra-violet. The absorption of the ultra-violet radiation takes place largely in the higher stratosphere, where it probably contributes to the atmospheric ionization (see **ionosphere**). The longer infra-red is absorbed mainly by dust and water vapor at lower levels, which accounts for the low temperature of the air at high altitudes.

SOLARIMETER. A **pyrheliometer** for direct readings of solar radiation intensity from sun and sky.

SOLARIZATION. (1) An actinic effect of sunlight or ultraviolet upon glass which results in a reduction in transparency, and sometimes permanent coloration. (2) A reversal of gradation sequence in a dense photographic image as a result of great overexposure.

SOLATION. The process of change from a **gel** to a **sol.** The gel is said to solate.

SOLEIL PLATE. A type of optical **compensator** somewhat like that of Babinet, but so constructed as to introduce the same relative phase-change over the entire field at once, instead of varying it progressively across the field.

SOLENOID. A coil which may consist of one or more layers of windings. It is the basis of all forms of the **electromagnet,** and is thus part of the working-mechanism of many electrically-operated devices.

The magnetic field strength within a solenoid whose length L is much greater than its diameter is nearly uniform and is approximately

$$B = \mu H = \mu NI/L,$$

where N is the number of turns and I is the current (rationalized units).

SOLENOID, RING. A toroidal or ring-shaped coil of wire.

SOLENOID, STRAIGHT. A coil of wire wound in the form of a cylinder, usually a circular cylinder.

SOLID. (1) A state of aggregation in which the substance possesses both definite volume and definite shape. Solids possess elasticity both of shape and bulk, i.e., they resist any force that tends to alter their volume or form. Solids are characterized by very stable surfaces of distinct outline on all sides. (2) A geometric solid is any portion of space which is occupied conceptually by a physical solid.

SOLID, GEOMETRIC. See **solid (2).**

SOLID OF REVOLUTION. A solid generated by the revolution of a plane area about a line, the axis of revolution.

SOLID SOLUTION. A homogeneous solid in which atoms or molecules of one type have been partially replaced by other atoms or molecules without altering the basic crystal structure. The formation of such a mixed crystal is usually a sign of **isomorphism,** although this is not necessarily the case in **substitutional alloys.**

SOLID-STATE PHYSICS. Generally speaking, that branch of physics which deals with the structure and properties of solids. It may perhaps be divided into the anatomy of solids, i.e., **crystallography,** theory of the structure of **metals, alloys, ionic crystals,** etc., **cohesive** forces, **band structure,** etc., the physiology of solids, i.e., **specific heats, thermal vibrations, thermal** and **electrical conductivity, intrinsic semiconductivity, superconductivity, photoconductivity,** magnetic and dielectric properties, etc.; the pathology of solids, i.e., **impurity semiconductivity, plasticity, lattice defects, color centers, dislocation** theory, **crystal growth,** etc. One may observe a shift of interest from the former to the latter aspects, as understanding of the solid state progresses.

SOLIDUS CURVE. A curve representing the **equilibrium** between the solid phase and the liquid phase in a **condensed system** of two **components.** The relationship is reduced to a two-dimensional curve by disregarding the influence of the vapor phase. The points on the solidus curve are obtained by plotting the temperature at which the last of the liquid phase solidifies, against the composition, usually in terms of the percentage composition of one of the two components.

SOLIQUID. A dispersed system of a solid in a liquid. (See **colloid.**)

SOLUBILITY. A property of a substance by virtue of which it forms mixtures with other substances which are chemically and physically homogeneous throughout. The degree of solubility (often spoken of as "solubility") is the concentration of a solute in a saturated solution at any given temperature. The degree of solubility of most substances increases with rise in temperature, but there are cases (notably the organic salts of calcium) where a substance is more soluble in cold than in hot solvents.

SOLUBILITY, APPARENT. The total amount of a salt present in unit volume of a solution. (See **solubility, real.**)

SOLUBILITY COEFFICIENT OF GASES. The volume of gas, under the experimental conditions of pressure and temperature, dissolved by unit volume of solvent.

SOLUBILITY CURVE. The graph showing the variation with temperature of the concentration by a substance in its **saturated solution** in a solvent.

SOLUBILITY PRODUCT. A numerical quantity dependent upon the temperature and the solvent, characteristic of **electrolytes.** It is the product of the concentrations of ions in a saturated solution and defines the degree of solubility of the substance. When the product of the ion concentrations exceeds the solubility product, precipitation commonly results. Strictly speaking, the product of the activities of the ions should be used to determine the solubility product, but in many cases the results obtained using concentrations, as suggested by Nernst, are correct.

SOLUBILITY, REAL. The amount of nonionized dissolved salt that exists in unit volume of a solution, as distinguished from "apparent" solubility, which includes both the nonionized and ionized salt.

SOLUBILITY, RETROGRADE. (1) Solubility which decreases with rise in temperature, as that of sodium sulfate above 34°C, and that of a number of organic calcium salts. (2) A particular case in the conversion of a one- to a two-phase system for a three-component system involving two partially-miscible liquids.

SOLUTE. In a solution of two components in which the component present in excess is called the solvent, the other component is termed the solute.

SOLUTION. (1) A homogeneous mixture of substances which forms a single **phase.** Gases are mutually soluble in all proportions; liquids may dissolve gases, other liquids, and solids; and solutions of solids in solids are known. (2) The process of finding a required

result by the use of certain given data, previously known facts or methods, and newly observed relations; or the result of this process. For example, the process of finding the **root(s)** of an equation; or the root(s) themselves.

SOLUTION, COLLOIDAL (DISPERSE SYSTEM). A heterogeneous system consisting of more than one **phase.** The solvent is termed the continuous phase and the suspended matter the disperse phase. The disperse phase consists of minute aggregated particles, each of which is very much larger than any of the constituent molecules. (This property distinguishes colloidal from real solutions.) If the disperse phase is a solid, the system is termed a colloid; if liquid, an emulsoid or emulsion (provided the particles of disperse phase are quite large).

SOLUTION(S), CONJUGATE. The two liquid phases of a partly-miscible, two-component system in equilibrium, in which one phase is a saturated solution of component A in component B, and the other phase is a saturated solution of component B in a component A.

SOLUTION, DILUTE. The application of thermodynamics to **colligative properties** of solutions gives quantitative results only for ideal solutions. (See **solution, ideal.**) Dilute solutions approach the behavior of ideal solutions. The range of concentrations over which the relations obtained for ideal solutions hold for dilute solutions will vary with the nature of the constituents, namely with the solute and the solvent.

SOLUTIONS, DILUTE, THEORY OF. Van't Hoff's theory that substances in dilute solution obey the same laws that apply to gases. Used in the calculation of osmotic pressure.

SOLUTION, IDEAL. A solution which behaves exactly in accordance with the **Raoult law** and various relationships derived from it, at all temperatures and concentrations. Many real solutions approach ideal behavior more or less closely when highly dilute, deviations from ideality becoming more marked the higher the concentration.

SOLUTION(S), ISOPIESTIC. Solutions that exert equal **vapor pressures.**

SOLUTION, MOLAL. A solution that contains a mole of solute dissolved in one kilogram of solvent.

SOLUTION, MOLAR. A solution that contains a mole of solute dissolved in one liter of solution.

SOLUTION, NORMAL. A solution containing one gram equivalent of a particular **constituent** of the solute in a liter of solution.

SOLUTION PRESSURE. (1) The force impelling molecules or atoms to cross a **phase** boundary and enter into solution. (2) A term introduced by Nernst to denote the property possessed by metals, hydrogen, and certain non-metals, whereby they tend to pass into solution as ions. However, it has not been found possible to devise a method for the measurement of the absolute potential between an electrode and a solution of its ions. (For a further discussion, see **electrolytic solution pressure.**)

SOLUTION, SATURATED. A solution containing the maximum proportion of solute to solvent at that temperature under **equilibrium** conditions; in other words, a solution which does not change in concentration of solute as more solute is added.

SOLUTION, SATURATED, INCONGRUENT. A solution of two or more components, which is unsaturated with respect to one solid phase present, and saturated with respect to a second solid phase present, with the added circumstance that there is a component in common to all three phases (i.e., the solution and the two solid phases). As the solution becomes more concentrated, one solid phase enters into solution, while the second solid phase (e.g., a double salt) separates from solution.

SOLUTION, SINGULAR. (1) A solution whose **vapor pressure** curve as a function of composition shows a maximum or minimum indicating the formation of a **constant boiling mixture**, as in aqueous solutions of alcohol. (2) For the use of this term in mathematics, see **singular solution.**

SOLUTION, STANDARD. Any solution of known, definite concentration.

SOLUTION, SUPERSATURATED. A solution which contains a greater quantity of dis-

solved solute than that which can exist at the given temperature in stable **equilibrium** with the solid solute. Supersaturated solutions are **metastable systems** in which a true equilibrium is not established. Addition of solid substance, stirring, friction, etc., causes the separation of the excess of solute.

SOLVATION OF IONS. The attachment of molecules of **solvent to ions.**

SOLVENT. Usually the term denotes a liquid which dissolves another compound to form a homogeneous one-phase liquid mixture. In a wider meaning, the term denotes that component of a gaseous, liquid, or solid mixture which is present in excess over all other components of the system.

SOLVENT, DISSOCIATING. A solvent in which solutes that associate in many other solvents enter into solution as single molecules. Thus, various carboxylic acids associate and hence give abnormal elevations of the boiling point, abnormal depressions of the freezing point, etc., in many organic solvents; in water, however, they do not associate. Therefore, water is called a dissociating solvent for such solutes.

SOLVENT, IMMISCIBLE. A liquid that dissolves or extracts a substance from solution in another solvent without mixing with the other solvent.

SOLVENT, NONPOLAR. A solvent whose constituent molecules do not possess permanent **dipole moments** and which does not form ionized solutions.

SOLVENT, NORMAL. A solvent that does not undergo **chemical association,** the formation of complexes between its molecules.

SOLVENT, POLAR. A solvent consisting of polar molecules, i.e., molecules that exert local electrical forces. In such solvents **electrolytes** (salts, acids, and bases) dissociate into ions, and form electrically-conducting solutions. Water, ammonia, and sulfur dioxide are representative polar solvents.

SOLVOLYSIS. A generalized conception of the relation between a solvent and a solute (i.e., a relation between two components of a single-phase homogeneous system) whereby the solvent molecule donates a proton to, or accepts a proton from a molecule of solute, or both, forming one or more different molecules. A particular case of special interest occurs when water is used as solvent, in which case the interaction between solute and solvent is called **hydrolysis.**

SOMMERFELD FORMULA. An approximate propagation relationship for distances short enough that the earth's curvature may be neglected. It states that

$$\mathcal{E} = \frac{K\sqrt{PA}}{d}$$

where $\mathcal{E}$ is the field strength; K is an antenna constant; P is the radiated power, d is the distance away from the antenna and A is relationship involving the frequency, the distance, and the soil conductivity.

SOMMERFELD LAW OF REGULAR OR RELATIVISTIC DOUBLETS. The relationship:

$$\Delta\nu = \frac{\alpha^2 R(Z - \sigma_2)^4}{n^3(l + 1)}$$

where σ_2 is a **screening constant,** and the smallest value of l ($= k - 1$) is 1.

SONAR. A term formed from the contraction of sound navigation and ranging. Sonar equipment is employed for underwater detection, ranging, and depth measurement. In a process analogous to that used in **radar,** sonic or supersonic pulses are transmitted, reflected from an object, and received at the point of transmission. The required time-interval is used as a measure of the distance between the reflecting object and the transmitter.

SONAR, COMMUNICATION. Signaling from ship to ship underwater by means of **sonar** equipment. The sound signal in the water may be a replica of the original voice or telegraph frequency, or it may be a modulated **ultrasonic frequency.** In the latter case the carrier frequency is usually below 100 kc because of the very high **attenuation at the** higher frequencies.

SONAR, DIRECTION AND RANGING. The detection of underwater objects by the use of **sonar** equipment. An **oscillator** operates at a fixed frequency, usually between 10 and 50 kc. A switch connects the power **amplifier** of the oscillator to a subaqueous **loudspeaker-**

microphone used as a loudspeaker. After a few seconds, the switch then connects the amplifier to the loudspeaker-microphone used as a microphone. If a reflected sound impulse is received, it will be indicated by a "pip" on a **cathode ray tube** or as a "ping" on an air loudspeaker. The directional pattern of the loudspeaker-microphone enables the direction to be determined, while the time-delay of the returning echo furnishes information on the range.

SONAR, ECHO DEPTH SOUNDING. See **acoustic depth finding, echo method.**

SONE. A unit of **loudness.** By definition, a simple tone of frequency 1000 cycles per second, 40 **decibels** above a listener's threshold, produces a loudness of 1 sone. The loudness of any sound that is judged by the listener to be n times that of the 1-sone tone is n sones. The loudness scale is a relation between loudness and **level above threshold** for a particular listener. In presenting data relating loudness in sones to **sound pressure level,** or in averaging the loudness scales of several listeners, the thresholds (measured or assumed) should be specified. The term "loudness unit" has been used for the basic subdivision of a loudness scale based on group judgment on which a loudness level of 40 **phons** has a loudness of approximately 1000 loudness units. For example, see Figure 1 of *American Standard for Noise Measurement,* **Z24.2**-1942.

SONIC DEPTH FINDER. See **sonar.**

SONICS. A term coined by Theodor F. Huter and Richard H. Bolt to encompass the "analysis, testing and processing of materials and products by the use of mechanical vibratory energy."

SORET EFFECT. An alternative term for the phenomenon of **thermal diffusion.**

SORPTION. A generalized term for the many phenomena commonly included under the terms **adsorption** and **absorption** when the nature of the phenomenon involved in a particular case is unknown or indefinite.

SOSOLOID. A dispersed system of a solid phase in a solid phase.

SOUND. (1) An alternation in pressure, stress, particle displacement, particle velocity, and so forth, which is propagated in an elastic material, or the superposition of such propagated alterations. (2) Also, auditory sensation which is usually evoked by the alterations described above. In case of possible confusion the terms "sound wave" or "elastic wave" may be used for concept (1), and the term "sound sensation" for concept (2).

SOUND ABSORBERS, FUNCTIONAL. Sound absorbers usually made in the form of thin shells of acoustically absorbing material and suspended on wires. They are high efficiency absorbers and are often used in locations where appearance is not a factor.

SOUND ABSORPTION. The process by which sound energy is diminished in passing through a medium or in striking a surface.

SOUND ABSORPTION COEFFICIENT (ACOUSTICAL ABSORPTIVITY). The fraction of incident sound energy absorbed by the surface or medium. The surface is considered part of an infinite area. The value of the coefficient is a function of the angle of incidence of the sound.

SOUND ANALYZER. A device for measuring the **band pressure level** or pressure spectrum level (see **spectrum level, pressure**) of a sound as a function of frequency.

SOUND ARTICULATION. See **articulation, sound.**

SOUND BAND PRESSURE LEVEL. The **band pressure level** of a sound for a specified frequency band is the effective sound pressure level for the sound energy contained within the band. The width of the band and the reference pressure must be specified. When measuring thermal noise, the **standard deviation** of the sound pressure readings will not exceed about 10 per cent if the product of the band width in cycles per second and the integration time in seconds exceeds 20.

SOUND CHANNEL PROPAGATION. The enhanced propagation of sound through a layer of a fluid because of focussing effects produced by variations in the sound velocity.

SOUND, DIFFUSE. In a given region, sound which has uniform energy density (see **sound energy density**) and is such that all directions

of energy flux (see **sound energy flux**) at all parts of the region are equally probable.

SOUND DISTRIBUTOR, HIGH FREQUENCY. A loudspeaker cone containing a system of vanes, by means of which it is possible to spread the high frequency radiation and thereby maintain uniform directional characteristics with respect to frequency.

SOUND ENERGY. The sound energy of a given part of a medium is the total energy in this part of the medium minus the energy which would exist in the same part of the medium with no sound waves present.

SOUND-ENERGY DENSITY. The sound-energy density at a point in a sound field is the **sound energy** contained in a given infinitesimal part of the medium divided by the volume of that part of the medium. The commonly used unit is the erg per cubic centimeter. The terms "instantaneous energy density" have meanings analogous to the related terms used for **sound pressure.** In speaking of average energy density in general, it is necessary to distinguish between the space average (at a given instant) and the time average (at a given point).

SOUND ENERGY FLUX. The average rate of flow of **sound energy** for one period through any specified area The commonly used unit is the erg per second Expressed mathematically, the sound-energy flux J is

$$J = \frac{1}{T}\int_0^T pSv_a dt,$$

where T = an integral number of periods or a time long compared to a period, p = the instantaneous **sound pressure** over the area S, v_a = the component of the instantaneous particle velocity (see **velocity, particle**) in the direction a, normal to the area S. In a medium of density ρ, for a plane or spherical free wave having a velocity of propagation c, the sound-energy flux through the area S, corresponding to an effective sound pressure p, is

$$J = \frac{p^2 S}{\rho c} \cos \theta,$$

θ = the angle between the direction of propagation of the sound and the normal to the area S.

SOUND-ENERGY FLUX DENSITY. See **sound intensity.**

SOUND-ENERGY FLUX DENSITY LEVEL. See **sound intensity level.**

SOUND FIELD. A region containing sound waves.

SOUND INTENSITY (SPECIFIC SOUND-ENERGY FLUX) (SOUND-ENERGY FLUX DENSITY). The sound intensity in a specified direction at a point is the average rate of **sound energy** transmitted in the specified direction through a unit area normal to this direction at the point considered. The commonly used unit is the erg per second per square centimeter, but sound intensity may also be expressed in watts per square centimeter. The sound intensity in any specified direction, a, of a sound field is the sound-energy flux through a unit area normal to that direction. This is given by the expression

$$I_a = \frac{1}{T}\int_0^T pv_a dt,$$

where T = an integral number of periods or a time long compared to a period, p = the instantaneous sound pressure, v_a = the component of the instantaneous particle velocity in the direction a. In the case of a free plane or spherical wave having the effective sound pressure, p, the velocity of propagation, c, in a medium of density, ρ, the intensity in the direction of propagation is given by:

$$I = \frac{p^2}{\rho c}.$$

SOUND INTENSITY LEVEL (SPECIFIC SOUND-ENERGY FLUX LEVEL) (SOUND-ENERGY FLUX DENSITY LEVEL). The intensity level, in **decibels**, of a sound is 10 times the logarithm to the base 10 of the ratio of the intensity of this sound to the reference intensity The reference intensity shall be stated explicitly. In discussing sound measurements made with pressure or velocity microphones, especially in enclosures involving normal modes of vibration or in sound fields containing standing waves, caution must be observed in using the terms "intensity" and "intensity level" Under such conditions it is more desirable to use the terms **"sound pressure level"** or **"sound velocity level,"** since the

relationship between the intensity and the pressure or velocity is generally unknown.

SOUND LEVEL. The sound level, at a point in a sound field has been defined by the American Standards Association as the weighted sound pressure level determined in the manner specified in the *American Standard Sound Level Meters for Measurement of Noise and Other Sounds,* **Z24.3**-1944, or its latest revision. The meter reading (in decibels) corresponds to a value of the sound pressure integrated over the audible frequency range with a specified frequency weighting and integration time.

SOUND LEVEL METER. An instrument including a **microphone,** an **amplifier,** an output meter, and frequency weighting networks for the measurement of noise and sound levels in a specified manner; the measurements are intended to approximate the **loudness level** which would be obtained by the more elaborate ear balance method.

SOUND OCTAVE-BAND PRESSURE LEVEL (OCTAVE PRESSURE LEVEL). The **band pressure level** for a frequency band corresponding to a specified octave. The location of the octave-band pressure level on a frequency scale is usually specified as the geometric mean of the upper and lower frequencies of the octave.

SOUND POWER OF A SOURCE. The total **sound energy** radiated by the source per unit of time. The commonly used unit is the erg per second but the power may also be expressed in watts.

SOUND-POWERED PHONE. A point-to-point telephone communicating system employing no batteries, amplifiers or other means of external power The human voice produces a sound wave which actuates the microphone at the transmitting end. The microphone converts the acoustic energy into the corresponding electric energy. This energy is carried on wires to the receiving end, where the electrical variations are converted into sound vibrations by the receiver.

SOUND PRESSURE, EFFECTIVE (ROOT-MEAN-SQUARE SOUND PRESSURE). The root-mean-square value of the instantaneous sound pressures, over a time interval, at the point under consideration. In the case of periodic sound pressures, the interval must be an integral number of periods or an interval long compared to a period. In the case of nonperiodic sound pressures, the interval should be long enough to make the value obtained essentially independent of small changes in the length of the interval. The term "effective sound pressure" is frequently shortened to "sound pressure."

SOUND PRESSURE, INSTANTANEOUS. The total instantaneous pressure at a point under consideration minus the static pressure at that point The commonly used unit is the **microbar.** Sometimes called **excess sound pressure.**

SOUND PRESSURE LEVEL. The sound pressure level, in decibels, of a sound is 20 times the logarithm to the base 10 of the ratio of the pressure of this sound to the reference pressure The reference pressure should be explicitly stated. The following reference pressures are in common use: (1) 2×10^{-4} microbar; (2) 1 microbar. Reference pressure (1) has been in general use for measurements dealing with hearing and sound-level measurements in air and liquids, while (2) has gained widespread use for calibrations, and many types of sound-level measurements in liquids. It is to be noted that in many sound fields the sound pressure ratios are not proportional to the square root of corresponding power ratios and hence cannot be expressed in decibels in the strict sense; however, it is common practice to extend the use of the decibel to these cases.

SOUND PRESSURE, MAXIMUM. The maximum sound pressure for any given cycle of a periodic wave is the maximum absolute value of the instantaneous sound pressure occurring during that cycle. The commonly used unit is the microbar In the case of a sinusoidal sound wave this maximum sound pressure is also called the pressure amplitude.

SOUND PRESSURE, PEAK. For any specified time interval, the maximum absolute value of the instantaneous sound pressure in that interval. The commonly used unit is the **microbar.** In the case of a periodic wave, if the time interval considered is a complete period, the peak sound pressure becomes identical with the maximum sound pressure. **(See sound pressure, maximum.)**

SOUND PRESSURE SPECTRUM LEVEL. At a specified frequency, the effective sound pressure level for the sound energy contained within a band 1 cycle per second wide, centered at the specified frequency. Ordinarily this has significance only for sound having a continuous distribution of energy within the frequency range under consideration. The reference pressure should be explicitly stated. Since in practice it is necessary to employ filters having an effective band width greater than 1 cycle per second, the pressure spectrum level is in general a computed quantity. For a sound having a uniform distribution of energy, the computation can be made as follows: Let L_{ps} be the desired pressure spectrum level, p be the effective pressure measured through the filter system, p_0 be reference sound pressure, Δf be the effective band width of the filter system, and $\Delta_0 f$ be the reference band width (1 cycle per second), then

$$L_{ps} = 10 \log_{10} \left[\frac{p^2/\Delta f}{p_0^2 \quad \Delta_0 f} \right].$$

For computational purposes, if L_p is the band pressure level observed through the filter, the above relation reduces to

$$L_{ps} = L_p - 10 \log_{10} \frac{\Delta f}{\Delta_0 f}.$$

SOUND PROBE. A device fo exploring a **sound field** without significantly disturbing the field in the region being explored.

SOUND PROOFING. The use of acoustical absorbing materials in walls and partitions to cut down the transmission of sound from one room to another.

SOUND RANGING, GUN. The detection of gun emplacements by recording the time of sound reception at three or more stations.

SOUND RANGING IN AIR. The detection of the true position of the sound source from an unseen aerial source such as an airplane.

SOUND RECORDER, PHOTOGRAPHIC (OPTICAL SOUND RECORDER). Equipment incorporating means for producing a modulated light beam and means for moving a light-sensitive medium relative to the beam for recording signals derived from sound signals.

SOUND RECORDING SYSTEM. A combination of transducing devices (see **transducer**) and associated equipment suitable for storing sound in a form capable of subsequent reproduction.

SOUND REFLECTION COEFFICIENT (ACOUSTICAL REFLECTIVITY). The sound reflection coefficient of a surface not a generator is the ratio of the rate of flow of **sound energy** reflected from the surface, on the side of incidence, to the incident rate of flow. Unless otherwise specified, all possible directions of incident flow are assumed to be equally probable. Also, unless otherwise stated, the values given apply to a portion of an infinite surface, thus eliminating edge effects.

SOUND REINFORCEMENT. The use of public address systems in large broadcasting studios and radio theaters to enable the studio audience to hear all portions of the program in proper perspective, whether the sound originates on the stage of the studio or at some remote point.

SOUND REINFORCING SYSTEM. A system in a theater or hall, consisting of microphones distributed on the stage and in the orchestra and loudspeakers suspended above the stage. The purpose is to make the **sound energy density,** due to the original sound source and the loudspeakers, as nearly uniform as possible.

SOUND REPRODUCING SYSTEM. A combination of transducing devices (see **transducer**) and associated equipment for reproducing recorded sound

SOUND REPRODUCING SYSTEM, AUDITORY PERCEPTIVE. A **sound reproducing system** in which the ears of the auditor are effectively transferred to the original scene of action, e.g., by picking up the sound on several microphones, amplifying the signal in separate channels, with each channel feeding a separate loudspeaker. The loudspeakers are arranged on the stage in the same positions as the microphones on the pickup stage.

SOUND REPRODUCING SYSTEM, BINAURAL. A **sound reproducing system** in which two microphones simulate the ears of a dummy, each receiving the component of

the original sound that would normally be received by a human ear at that position. Each component is reproduced through a separate audio channel; each channel terminates in a telephone receiver. The sound produced at the ears of the observer is then identical to what would have been produced at the original position of the dummy.

SOUND REPRODUCING SYSTEM, MAGNETIC WIRE. A **sound reproducing system** employing **magnetic tape** for the recording and reproduction of sound. The output of a microphone or radio receiver is amplified and sent through an equalizer. A recording head, actuated by the amplifier, magnetizes the wire or tape in a manner corresponding to the undulations in the original sound wave In reproducing, the wire or tape is pulled past the recording head at the speed of the original recording. The magnetic undulations in the wire generate a voltage in the coil of the recording head which corresponds to the original sound vibrations. The output of the reproducing head is equalized and amplified and then fed to a loudspeaker.

SOUND REPRODUCING SYSTEM, MONAURAL. A **sound reproducing system** consisting of one or more microphones with preamplifiers and mixers, voltage amplifier, attenuator, power amplifier and one or more loudspeakers. It is used for sound reinforcement and public address systems.

SOUND REPRODUCING SYSTEM, PHONOGRAPH. A **sound reproducing system** in which the general studio equipment is quite similar to that of a broadcasting studio, except that an **equalizer** is used to attenuate the output below 800 cycles/sec to yield approximately uniform amplitude in that region. A cutter actuated by the amplifier cuts a spiral wavy path in the revolving record corresponding to the undulations in the original sound wave. In reproducing the record is turned at constant speed. A stylus or needle follows the wavy spiral groove and generates voltages corresponding to the undulations in the record. The output is equalized to compensate for the equalization in the original recording, and is passed through a low pass filter. The resultant signal is passed through a power amplifier which drives the loudspeaker.

SOUND REPRODUCING SYSTEM, RADIO. A **sound reproducing system** in which the outputs of several microphones are amplified and fed to **attenuators** and then through **filters, equalizers** and **compressors** to eliminate noise and frequency deficiencies, and also to reduce the volume range. The output is passed through an **amplifier** and isolating amplifier, and is fed to the transmitter. A small part of the radio frequency energy radiated by the transmitter antenna is picked up by the receiving antenna, amplified in the radio frequency stages, combined with an intermediate frequency oscillator and fed into the first detector. The output of the first detector is amplified by the intermediate frequency amplifier and then fed to the second detector. The audio frequency output of the second detector is then fed to a power amplifier which drives a loudspeaker.

SOUND REPRODUCING SYSTEM, SOUND MOTION PICTURE. A **sound reproducing system** in which the outputs of several microphones are amplified and fed to **attenuators** and then through **filters, equalizers** and **compressors** to eliminate noise and frequency deficiencies and also to reduce the volume range. The output passes through an overall amplifier and feeds a light modulator and a monitoring system. By means of the optical system and light modulator, the electrical variations are recorded on the film into corresponding variations in density or in area.

SOUND REPRODUCING SYSTEM, TELEPHONE. A **sound reproducing system** consisting of a carbon microphone (see **microphone, carbon**), a telephone receiver, and a battery.

SOUND SOURCE, SIMPLE. A source which radiates sound uniformly in all directions under free-field conditions. (See **field, free.**)

SOUND SOURCE, STRENGTH OF (STRENGTH OF A SIMPLE SOURCE). The maximum instantaneous rate of volume displacement produced by the source when emitting a wave with sinusoidal time variation.

SOUND SYSTEM, STEREOPHONIC. A **sound reproducing system** in which a plurality of microphones, transmission channels, and loudspeakers is arranged so as to provide a

sensation of spatial distribution of the sound sources to the listener to the reproduction.

SOUND TRACK. A narrow band, usually along the margin of a sound film, which carries the sound record. In some cases, a plurality of such bands may be used.

SOUND TRACK, CLASS-A PUSH-PULL. Two single **sound tracks** side by side, the transmission of one being 180° out of phase with the transmission of the other. Both positive and negative halves of the sound wave are linearly recorded on each of the two tracks.

SOUND TRACK, CLASS-B PUSH-PULL. Two **sound tracks** side by side, one of which carries the positive half of the signal only, and the other the negative half. During the inoperative half cycle, each track transmits little or no light.

SOUND TRANSMISSION COEFFICIENT (ACOUSTICAL TRANSMITTIVITY). Of an interface or septum, the ratio of the transmitted to incident **sound energy.** The value of the coefficient is a function of the angle of incidence of the sound

SOUND VOLUME VELOCITY. The rate of flow of the medium through a specified area due to a sound wave The terms "instantaneous volume velocity," "effective volume velocity," "maximum volume velocity," and "peak volume velocity" have meanings which correspond with those of the related terms used for **sound pressure.**

SOUND WAVE, CIRCULARLY POLARIZED. An elliptically polarized sound wave (see **sound wave, elliptically polarized**) in which the displacement vector at any point rotates about the point with constant angular velocity and has a constant magnitude. A circularly polarized wave is equivalent to two superposed plane polarized waves of sinusoidal form in which the displacements have the same amplitude, lie in perpendicular planes, and are in quadrature.

SOUND WAVE, ELLIPTICALLY POLARIZED. A transverse wave in an elastic medium in which the displacement vector at any point rotates about the point and has a magnitude which varies as the radius vector of an ellipse. An elliptically polarized wave is equivalent to two superimposed plane-polarized waves of simple sinusoidal form in which the displacements lie in perpendicular planes and are in quadrature.

SOUND WAVE, PLANE POLARIZED (LINEARLY POLARIZED SOUND WAVE). At a point in an elastic medium, a transverse wave in which the displacements at all times lie in a fixed plane which is parallel to the direction of propagation The above definition is equivalent to stating that, in a plane-polarized sound wave, the displacement vector at any point lies in a fixed straight line passing through the point.

SOUND WAVES, MEAN FREE PATH FOR. In an enclosure, the average distance sound travels between successive reflections.

SOUNDER. A telegraph receiving instrument consisting of an **armature (2)** and an **electromagnet.** Each current pulse received actuates the armature, creating an audible click.

SOUNDING ELECTRODE. A **probe** used to make measurements in a **gas discharge.**

SOURCE. Any device which supplies energy, in the form of radiation, electric currents, sound waves, etc. Thus, in spectroscopy, the **arc** or **spark** that supplies light; in electrical circuits the **generator, battery,** or **oscillator** that supplies electrical energy; in sound recording, the device which supplies power to a **transducer.**

SOURCE, CIRCULAR RING. A curved line source (see **source, curved line**) in which the line forms a closed circle

SOURCE, CONE SURFACE. A truncated cone of paper or felted paper used in a direct radiator type loudspeaker. (See **loudspeaker, direct radiator.**)

SOURCE, CURVED LINE. A **source** composed of a large number of point sources (see **source, simple point**), usually of equal strength, vibrating in phase on the arc of a circle. The adjacent point sources are separated by equal, very small distances.

SOURCE, CURVED SURFACE. A portion of a spherical surface, large compared to the wavelength, and vibrating radially.

SOURCE, DOUBLET. Two simple point sources (see **source, simple point**), equal in

strength but opposite in phase, separated by a vanishingly small distance.

SOURCE IMPEDANCE. The impedance presented by the **source** to a **transducer.**

SOURCE LEVEL. The **sound intensity** at a point on the axis one yard from a source, measured in **decibels** above a reference level. In symbols, the source level S, in decibels, is given by

$$S = 10 \log \frac{I_0}{I_r},$$

where I_0 = intensity at a point on the axis one yard from the source, I_r = reference intensity, usually corresponding to an rms pressure of 1 dyne/cm^2.

SOURCE, NONUNIFORM PLANE CIRCULAR SURFACE. A plane circular surface with all parts vibrating in phase, but with the strength varying as a function of the distance from the center.

SOURCE, PLANE CIRCULAR SURFACE. A plane circular surface with all parts vibrating with the same strength and phase

SOURCE, PLANE SQUARE SURFACE. A plane square surface with all parts of the surface vibrating with the same strength and phase.

SOURCE, SIMPLE POINT. A small source which alternately injects fluid into a medium and then withdraws it.

SOURCE, STRAIGHT LINE. A large number of simple point sources (see **source, simple point**) of equal strength and phase arranged on a straight line and separated by equal and very small distances.

SOURCE, STRAIGHT LINE, NONUNIFORM. The same as a straight line source (see **source, straight line**), except that the strength of the point sources is a function of position along the line.

SOURCE, STRAIGHT LINE, TAPERED. A non-uniform straight line source (see **source, non-uniform straight line**) in which the strength varies linearly from its value at the center to zero at either end.

SPACE CHARGE. The electric charge carried by a cloud or stream of electrons or ions in a vacuum or a region of low gas pressure, when the charge is sufficient to produce local changes in the potential distribution. It is of importance in **thermionic tubes, photoelectric cells, ion accelerators,** etc.

SPACE-CHARGE GRID. See **grid, space-charge.**

SPACE CHARGE LIMITATION OF CURRENTS. It has been shown by Child that the current between a plane cathode and a parallel plane anode at a distance d from it, when the anode potential is V, cannot exceed a certain maximum value, determined by the modification of the electric field near the cathode as a result of the **space charge** of electrons in that region. If the electrons leave the cathode with zero speed, the maximum current per unit area of the cathode is

$$i = \frac{4\epsilon_0}{9} \sqrt{\frac{2e}{m}} \frac{V^{3/2}}{d^2}$$

where e and m are the electronic charge and mass, respectively, and ϵ_0 is the electric constant. Langmuir has extended the equation to include the case of a cylindrical cathode of radius a, surrounded by a coaxial cylindrical anode of radius b. The maximum current per unit length is then

$$i = \frac{8\pi\epsilon_0}{9} \sqrt{\frac{2e}{m}} \frac{V^{3/2}}{b(\ln b/a)^2}.$$

The dependence of the current on the $3/2$ power of the potential difference is general, and is the basis of the definition of **perveance.**

SPACE CHARGE REGION (PERTAINING TO SEMICONDUCTOR). A region in which the net charge density is significantly different from zero. (See also **depletion layer.**)

SPACE DIVERSITY. See **diversity reception.**

SPACE, EUCLIDEAN. See **Euclidean space.**

SPACE FACTOR. In **antenna arrays,** the summation of the radiation patterns of all elements with respect to their individual positions, amplitudes, and phases in the array. If all elements are identical, the radiation intensity of the entire array is the product of the radiation intensity of an individual element and the square of the space factor.

SPACE GROUP. When identical objects are placed at the lattice points of a **space lattice** a regular spacial array is obtained, which has, perhaps, **symmetry elements** over and above those of the **point group** of the original lattice. Thus, because of some symmetry property of the identical objects (that is, of the **unit cells,** in a crystal), there may exist **glide planes** and **screw axes** which define operations turning the structure into itself. It has been shown that there are only 230 different types of symmetry possible for such a system; these are the 230 **space groups** which are classified according to the symmetry elements they possess.

SPACE GROUP EXTINCTION. In **X-ray diffraction** by crystals, certain classes of reflections may be absent owing to the crystal having certain additional **symmetry elements** corresponding to its **space group,** over and above its crystal **point group symmetry.** The observation of this effect helps in analyzing the **crystal structure,** giving information about the symmetry of the **unit cell.**

SPACE, HILBERT. See **Hilbert space.**

SPACE LATTICE. A regular three-dimensional arrangement of points constructed by the repeated application of the **primitive translations** which carry a unit cell into its neighbor Each point in the lattice has exactly the same environment and the lengths and orientations of the primitive translations fix the type of the lattice There are only fourteen kinds of simple space lattice, which are classified according to their symmetry type, as follows:

Symmetry Type	*Lattice Type*
Cubic	Simple cube; face-centered cube; body-centered cube.
Tetragonal	Tetragonal prism; body-centered tetragonal prism.
Orthorhombic	Rectangular prism; body-centered rectangular prism; rhombic prism; body-centered rhombic prism.
Monoclinic	Monoclinic parallelepiped; monoclinic, one-face centered.
Triclinic	Triclinic parallelepiped.
Hexagonal	Hexagonal prism.
Rhomboidal	Rhombohedron.

SPACE-LIKE SURFACE IN SPACE-TIME. A three-dimensional surface such that no point on it lies within the **absolute future** or **absolute past** of any other point. A particular case is any surface t = constant.

SPACE-LIKE VECTOR. A four-vector A_μ in **Minkowski space** such that

$$A_\mu A_\mu > 0.$$

SPACE, MINKOWSKI. See **Minkowski space.**

SPACE PATTERN. A geometrical pattern appearing on a test chart designed for the measurement of geometric **distortion** in television receivers. The RETMA Ball Chart is a specific example of a space pattern.

SPACE-TIME. A space of four dimensions which specify the space and time coordinates of an **event.** In the absence of a gravitational field, space-time reduces to **Minkowski space.**

SPACE-TIME PATH OF A CLASSICAL PARTICLE. A curve drawn in **space-time** to represent the position of a particle as a function of time.

SPACE WAVE. See **wave, space.**

SPACED ANTENNA. See **antenna, spaced.**

SPACING WAVE (BACK WAVE). See **wave, back.**

SPALLATION. A type of **nuclear reaction** in which several small particles are ejected from the nucleus. Examples are:

$$Bi^{209} + He^{1} \rightarrow At^{210} + 3n$$

$$As^{72} + H^{2} \rightarrow Mn^{52} + \text{unknown fragments.}$$

SPARK. An electric spark is a sudden breakdown of the insulating strength of the dielectric separating two electrodes, due to the formation of ions by an intense electric field, accompanied by a rush of electricity across the "spark gap," and a flash of light indicating very high temperature. Unlike the arc, glow, and brush discharges, the spark is of very short duration. It may be oscillatory or intermittent, several discharges taking place in quick succession. In gases, the spark takes place only at appreciable pressures, such as normal atmospheric pressure.

If the voltage across a spark gap is progressively raised, a spark passes when it has become sufficiently high. The lowest voltage at which the spark will pass is the "sparking potential"; but there is usually a time interval, called the "spark lag," between the at-

tainment of this voltage and the passage of the spark. Also the voltage may be increased for a moment considerably above this value without producing a spark. These characteristics depend upon the condition of the gas, especially upon the ions and the vapors present in it. After one spark has passed, others follow at lower sparking potential, because of the ions already formed; and this is also true if the "pilot spark" takes place across another neighboring spark gap. Paschen found that for a given pressure the sparking potential is a nearly linear function of the length of the gap, and for a given gap it is a nearly linear function of the pressure. For spherical terminals, the relation is so definite that the "sphere gap" is often used as a rough measure of high voltages. Thus with spherical electrodes 5 cm in diameter, a 2-cm spark in air at normal pressure corresponds to a potential difference of 56,300 volts; a 5-cm gap to 102,250 volts. With 10-cm spheres, the corresponding voltages are 59,460 and 123,850.

SPARK-GAP MODULATION. See **modulation, spark-gap.**

SPARK LINE (ION LINE). A spectral line produced by radiation from ions (a loose term; see **arc line**).

SPARK TRANSMITTER. See **transmitter, spark.**

SPATIAL POLAR COORDINATES. See **spherical polar coordinates.**

SPEAKER. See **loudspeaker.**

SPECIAL RELATIVITY THEORY. See **relativity theory, special.**

SPECIFIC ACOUSTIC IMPEDANCE. See **impedance, specific acoustic.**

SPECIFIC ACOUSTIC REACTANCE. See **reactance, specific acoustic.**

SPECIFIC ACOUSTIC RESISTANCE. See **resistance, specific acoustic.**

SPECIFIC ACTIVITY. (1) The **activity** of a radioisotope of an element per unit weight of element present in the sample. (2) The activity per unit mass of a pure radionuclide. (3) The activity per unit weight of any sample of radioactive material. Specific activity is commonly given in a wide variety of units (e.g., millicuries per gram, disintegrations per second per milligram, counts per minute per milligram, etc.).

SPECIFIC ELECTRONIC CHARGE. See **electronic charge, specific.**

SPECIFIC GRAVITY. The ratio between the **density** of a substance at a given temperature and the density of some substance assumed as standard. For liquids and solids the standard assumed is either the density of distilled water at 4°C, or the density of distilled water at 60°F. (This value is often used in calibrating industrial **hydrometers.**) For gases the standards are air, hydrogen, or oxygen at 0°C, and a pressure of 760 millimeters of mercury, or distilled water at 4°C The specific gravity is a relative property that varies with the temperature. The conventional symbol for specific gravity is $d_t^{t_1}$, where t_1 is the temperature of the substance and t_2 is the temperature of the standard.

SPECIFIC HEAT. See **heat, specific.**

SPECIFIC HEAT, ELECTRONIC. See **electronic specific heat.**

SPECIFIC IONIZATION. See **ionization, specific.**

SPECIFIC SOUND - ENERGY FLUX LEVEL. See **sound intensity level.**

SPECIFIC SURFACE. The surface, or area, of a substance or entity per unit volume; obtained by dividing the area by the volume, and expressed in reciprocal units of length

SPECIFIC VOLUME. The volume of a substance or entity per unit mass, obtained by dividing the volume by the mass; and expressed in units of length to the third power and reciprocal units of mass. Reciprocal of the **density.**

SPECTRAL ABSORPTION COEFFICIENT. See discussion of **absorption coefficient.**

SPECTRAL CENTROID. An average wavelength, computed especially for filters and other light-transmitting devices, by taking a weighted average, for each wavelength, of the **spectral distribution,** of the incident light, the **transmittance** of the device, and the **luminosity** data of the eye.

SPECTRAL CHARACTERISTIC. A relation, usually shown by a graph, between wavelength and some other variable. (1) In the

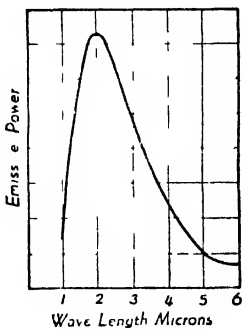
case of a luminescent screen, the spectral characteristic is the relation between wavelength and emitted radiant power per unit wavelength interval. (2) In a photoelectric device, it is the relation between wavelength and sensitivity per unit wavelength interval.

SPECTRAL COLORS. (1) Colors present in the spectrum of white light. (2) Colors that are represented by points on the **chromaticity diagram** that lie on straight lines between the **achromatic point** and the **spectrum locus.**

SPECTRAL DENSITY. The relative distribution of radiant energy throughout the spectrum. (See **spectral energy distribution.**)

SPECTRAL EMISSIVITY. See **emissivity.**

SPECTRAL ENERGY DISTRIBUTION. When radiation exhibiting a continuous spectrum is quantitatively analyzed, it is found that quite different amounts of power are represented by the radiation within equal ranges of wavelength or of frequency having different limits. The proportion in any such range depends upon the character of the source. If one divides the spectrum into small intervals of wavelength, say 10 angstroms, and plots the power output for each range as ordinate with



the mean wavelength of the interval as abscissa, the result is a curve showing the distribution of power through the spectrum. (See **Planck distribution law.**)

SPECTRAL LINES, PRESSURE WIDENING OF. See **pressure widening of spectral lines.**

SPECTRAL POSITION. The **effective wavelength** or frequency of an essentially monochromatic beam. Note that no beam of finite intensity is absolutely monochromatic. Note also that the effective wavelength of a beam of radiation in a narrow wavelength band at 3.0 microns in the diagram under **spectral energy distribution** would not be at the wavelength center of the band.

SPECTRAL RADIANT EMITTANCE. See **emittance.**

SPECTRAL SENSITIVITY. (1) The sensitivity of a **detector** measured for narrow spectral bands throughout the spectrum. (2) The emitted radiant-power wavelength distribution of a **luminescent screen** under a given condition of excitation. (3) The sensitivity of a photoelectric device in relation to the wavelength of the incident radiant energy.

Spectral sensitivity is usually displayed on a **spectral characteristic.**

SPECTRAL TRANSMISSION. The **transmission** of a plate of material measured for narrow spectral bands throughout the **spectrum.**

SPECTRAL TRANSMITTANCE. See **transmittance.**

SPECTROGRAM. A record produced by a spectrograph, i.e., a record of a spectroscopic process, commonly one obtained by photographic methods.

SPECTROGRAPH. An instrument used to produce a record of a **spectrum.** It may be considered to include the apparatus for producing the radiations or particles to be investigated; and includes the other necessary apparatus, i.e., that for selecting a desired portion of the radiations or particles; that for arranging them in a uniform beam; that for separating the beam into a spectrum; and that for recording the spectrum by photographic or other means. (See also **spectroscope.**)

SPECTROGRAPH, AUTOCOLLIMATING. A **spectrograph** in which the same lens that **collimates** the incident beam is used to focus the refracted beam.

SPECTROGRAPH, LITTROW. A spectrograph which makes use of a prism having an internally reflecting surface, functioning as a constant deviation prism. (See **prism, constant deviation.**)

SPECTROGRAPH, MAGNETIC. A device which utilizes the curvature of the path of a charged particle in a magnetic field to obtain

the velocity (hence energy) spectra of charged particles in radioactive decay. (See **mass spectrograph.**)

SPECTROGRAPH, MASS. See **mass spectrograph.**

SPECTROGRAPH, QUARTZ. A spectrograph designed to detect radiations in the ultraviolet region of the electromagnetic spectrum. The optical system is constructed of quartz because ordinary glass is opaque over most of the ultraviolet spectral region.

SPECTROGRAPH, VACUUM. A **spectrograph** in which the entire light path is *in vacuo.* The dispersive element is usually a concave reflection **grating.** In the absence of absorption by lenses and air, such an instrument may be operated for studies in the extreme ultraviolet.

SPECTROGRAPH, WEDGE. A **spectrograph** in which the **flux density** passing through the entrance slit is varied by means of an optical wedge or similar device.

SPECTROHELIOGRAPH. The spectroheliograph pictures the sun in its **spectrum.** Essentially the instrument consists of a high dispersion **spectrograph** with a second slit placed directly in front of the photographic plate so that the radiation from only one spectral line is received on the plate. The image of the sun moves across this slit.

SPECTROHELIOSCOPE. An instrument for observing an image of the entire sun in light of one wavelength. If used photographically, it is called a **spectroheliograph.**

SPECTROMETER. An instrument used to measure spectra or to determine **wavelengths** of the various radiations.

SPECTROMETER, BETA-RAY. An instrument used to determine the energy distribution of β-particles and secondary electrons.

SPECTROMETER, BETA-RAY, WITH ELECTROSTATIC FOCUSING. A β-ray **spectrometer** which uses a radial electrostatic field to provide **velocity focusing.**

SPECTROMETER, GAMMA-RAY. An instrument for determining the energy distribution of γ-rays.

SPECTROMETER, IONIZATION. See **Bragg spectrometer.**

SPECTROMETER, MAGNETIC, DOUBLE-FOCUSING. A **spectrometer** using shaped magnetic fields to focus ions whose velocities have a component normal to the median magnetic plane.

SPECTROMETER, MAGNETIC, SEMICIRCULAR-FOCUSING. A **spectrometer** in which a beam of ions of given **charge-to-mass ratio** (for example, electrons) are acted upon by a magnetic field perpendicular to their direction of motion. They will then be deflected in circular paths whose radii are dependent on the velocities of the ions.

SPECTROPHOTOMETER. An instrument for analyzing the **spectral energy distributions** of sources of light. It is thus a spectroradiometer for visible radiation. Various types are in use. A representative form includes a **monochromatic illuminator,** from the slit of which proceeds an isolated, narrow frequency range of the light under examination. This may be compared, by means of a **wedge photometer** device or otherwise, with the light of the same frequency range from a source whose spectral energy distribution is known. In interpreting the results, it is important to take into account the visibility factor (see **photometry**), and thus to distinguish between the relative absolute (energy) and apparent (visual) intensities for different wavelengths There are spectrophotometers which exhibit directly an approximate curve of apparent intensity distribution. A simple type consists of a spectrometer with a neutral absorbing wedge placed with the thick base over the upper end of the slit and the thin edge over the lower. The spectrum then appears as a strip whose upper margin, penetrating visibly to various distances into the region of greater absorption, corresponds to the distribution curve.

SPECTROPHOTOMETER, BECKMAN. (1) A **spectrophotometer** having a quartz prism, a concave focusing mirror, and several **photoemission** detectors. (2) Any spectrophotometer made by the Beckman Instruments, Inc.

SPECTROPHOTOMETER, BRACE-LEMON. See **Brace-Lemon spectrophotometer.**

SPECTROPHOTOMETER, GAERTNER. (1) A visual spectrophotometer comprising a Martens photometer (see **photometer, Mar-**

tens) and a constant-deviation spectrometer. (2) Any spectrophotometer made by the Wm. Gaertner Scientific Instrument Co.

SPECTROPHOTOMETER, GLAN. See **Glan spectrometer.**

SPECTROPHOTOMETER, HÜFNER. A visual **spectrophotometer** having a **rhomb** directly before the entrance slit of a constant-deviation spectrometer. (See **spectrometer, constant-deviation.**)

SPECTROPHOTOMETER, KÖNIG-MARTENS. A visual single-unit **spectrophotometer**, having a biprism and a Wollaston prism (see **prism, Wollaston**), the latter serving to polarize coincident images of the two halves of the entrance slit.

SPECTROPHOTOMETER, LUMMER-BRODHUN. A visual **spectrophotometer** containing a Lummer-Brodhun photometer cube. (See **photometer, Lummer-Brodhun.**)

SPECTROPHOTOMETER, PHOTOELECTRIC. A **spectrophotometer** containing a **photoelectric detector.**

SPECTROPHOTOMETRY, ABRIDGED. **Spectrophotometry** employing continuous spectra sources, but with various narrow band **filters** placed in the beam of light, under which condition the **transmittance** or **reflectance** of the sample is measured

SPECTROPHOTOMETRY, REFLECTANCE. Measurements of the intensity of various spectral frequencies or narrow bands of light reflected from surfaces, especially as applied to the specification of color, to problems in optical microchemistry, to uses in cytochemistry and histochemistry, and for other purposes.

SPECTRORADIOMETER. An instrument used to measure the spectral distribution of radiant energy (see **energy, radiant**) (See also **spectral energy distribution; radiation pyrometer.**)

SPECTROSCOPE. Many types of instrument for producing and viewing spectra are included under this term. Variations in form are due, not only to differences in principle, but also to the type of radiation to be examined, which ranges all the way from **infra-red** to **x-rays.**

The earlier spectroscopes, developed by Fraunhofer, Ångström, and others in the early part of the last century, adapted **Newton's** discovery of the **dispersion** of light by a **prism.** The essential features (Fig. 1) are a slit, S, a

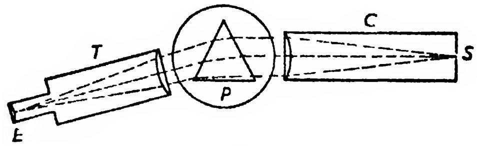


Fig 1. Diagram of simple prism spectroscope. *C*, collimator with slit *S*; *P*, prism; *T*, telescope for viewing spectrum at eyepiece *E*.

collimating lens, C, for rendering the light from the slit parallel before entering the prism, one or more dispersing prisms, P, and a **telescope**, T (or a **camera**), for forming images of the slit in the various wavelengths and thus providing a method for viewing or photographing the **spectrum.** The light passes through these in the order named, being deviated by the prism through various angles according to the wavelength. When a spectroscope is provided with a graduated circle for measuring deviations, it is called a "spectrometer." The "direct-vision" or non-deviation spectroscope, employing an **Amici prism,** is a compact instrument for qualitative purposes. The photographic spectroscope, known as a "spectrograph," is now almost universally used in spectral research (See **spectrograph.**)

Many modern spectroscopes employ the **diffraction grating** instead of the prism. In

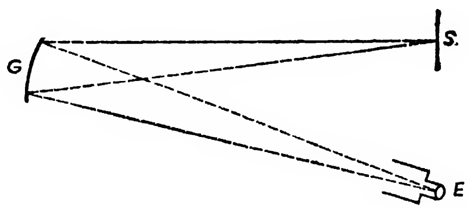


Fig 2. Diagram of concave grating spectroscope. *S*, slit; *G*, grating; *E*, eyepiece (or plate-holder).

the concave grating spectroscope, developed by Rowland, the collimating lens and telescope or camera objective are unnecessary because of the focusing effect of the grating itself (Fig 2).

SPECTROSCOPE, COMPARISON. An instrument for comparing spectra, as used, for example, to compare the absorption lines in the spectra of stars and other **astronomical**

objects, with the spectra of elements whose presence in the star is under investigation.

SPECTROSCOPE, DIRECT-VISION. A spectroscope without deflection of light, i.e., in which all components lie along one axis. (See **Amici prism.**)

SPECTROSCOPE, GRATING. A spectroscope in which the resolving element for light of different wavelengths is a **diffraction grating.**

SPECTROSCOPE, PRISM. A spectroscope in which the resolving element for light of different wavelengths is a **prism.**

SPECTROSCOPIC DISPLACEMENT, LAW OF. The arc spectrum (see **spectrum, arc**) of an element is similar, especially in regard to **fine structure,** to the first spark spectrum (see **spectrum, spark**) of the element one place higher in the periodic table, to the second spark spectrum of the element two places higher, and so on Since the lines in the arc spectrum are commonly those of the normal atom, while the first spark spectrum contains lines of the singly-ionized atom, the second spark spectrum, those of the double-ionized atom, and so on, this law asserts a similarity between the spectrum of an unionized atom, and that of a singly-ionized atom of an element one place higher in the periodic table, and that of a doubly-ionized atom two places higher in the table, etc.

SPECTROSCOPY. The branch of physical science treating the theory and interpretation of spectra.

SPECTRUM. (1) A visual display, a photographic record, or a plot of the distribution of the intensity (and sometimes the phase) of radiation of a given kind as a function of its wavelength, energy, frequency, momentum, mass or any related quantity. (2) A continuous range of frequencies, usually wide in extent, within which waves have some specified common characteristic, e.g., audio-frequency spectrum, radio-frequency spectrum, etc. (3) The resolution pattern of a group of masses over a region according to increasing mass, in which particles of a given mass are physically isolated from those of neighboring masses. (4) A mathematical concept denoting the types of resolutions which are associated with a given partial differential equation.

SPECTRUM, ABSORPTION. The spectrum resulting when the source is continuous radiation passed through an absorbing medium, commonly dark at some of those wavelengths for which the **emission spectrum** of the medium would be bright.

SPECTRUM, ALPHA PARTICLE. The distribution in energy or momentum of the **α-particles** emitted by a pure **radionuclide,** or, less commonly, by a mixture of radionuclides. Each α-emitting nuclide yields a characteristic spectrum consisting of one or more sharp lines, each line being due to a particular group of monoenergetic particles. When more than one group is present, the distribution is said to have fine structure; this results from transitions to more than one nuclear energy state of the product nuclide, the group of highest energy coming from the ground-state transition. In exceptional cases (RaC′ and ThC′), lines are observed due to groups that have very low intensities (10^{-6} to 10^{-4}) relative to those for the main groups The particles producing such lines are called long-range α-particles They result when the emitting nuclei are formed in excited states in the preceding **β-disintegration** (of RaC or ThC) and emit α-particles directly from the excited states, instead of becoming de-excited by the more usual gamma emission The normal **α-disintegration energy** is then augmented by the **excitation energy.**

SPECTRUM ANALYZER. A device for determining the frequency-energy distribution of a signal or group of signals The device generally consists of a selective receiver which is cyclically tuned through the desired frequency band. The receiver output may be displayed on the vertical axis of an **oscilloscope** whose horizontal sweep is related to the receiver sweep-rate, thus giving a visual indication of the frequency and relative strength of signals present

SPECTRUM, ARC. A **spectrum** produced at the temperature of the electric arc. The element or compound under investigation is placed between the electrodes forming the arc, or is applied to them as a coating; and the light emitted from the arc is examined spectroscopically. Because of the high temperature of an arc nearly all compounds are dissassociated, and the spectra of the elements rather than of the compound is obtained.

This makes arc spectra particularly useful in chemical analysis by spectroscopic methods. Also because of the relatively low potential differences required for an arc, the spectra of the normal (or, at most, singly-ionized elements) are obtained rather than the spectra of the ions, as is the case with spark spectra.

SPECTRUM, ATOMIC. The spectrum of radiation emitted by an excited **atom,** due to changes within the atom; in contrast to radiation arising from changes in the condition of a **molecule.** Atomic spectra are characterized by more or less sharply defined "lines," corresponding to pronounced maxima at certain frequencies or wavelengths, and representing radiation quanta of definite energy.

SPECTRUM, BAND. The spectra of molecules consist of groups or bands of closely spaced lines. These spectra were initially unresolved, and hence called bands in distinction to the sharp spectral lines of atoms. The bands of most molecules have now been resolved into their separate lines. Band spectra is the customary name for the spectra of molecules.

In nuclear physics, band spectra are useful in determining **nuclear spin** and **statistics,** and **isotopic abundances.**

SPECTRUM, BETA-RAY. (1) The distribution in energy or momentum of the β-particles (not including conversion electrons) emitted in a β-decay process. The β-ray spectrum is always continuous up to a maximum energy. Its shape depends upon the nature of the particular β-decay process (2) Sometimes and loosely, the energy spectrum of the electrons emitted by a radioactive source, irrespective of their origin In addition to the continuous spectrum of definition (1), it may show lines due to internal conversion or to Auger electrons.

SPECTRUM, CHANNELED. A spectrum in which there are interference bands, usually produced by the interaction of light rays approximately one half wavelength apart in phase, as those resulting from reflection from parallel surfaces.

SPECTRUM, CHARGE-TRANSFER. A term applied by Mullikan to spectra resulting from the transitions of an electron between a bonding and an antibonding orbital.

SPECTRUM, COMPARISON. A **spectrum** used as a standard for comparison to other spectra in spectrographic work, commonly by photographic methods. Because of the large number of well-known lines, the iron **arc** spectrum is very commonly used for a comparison spectrum. Particularly with prism **spectrometers** the accuracy of interpolation between two nearby, known spectral lines is far greater than could be obtained by the use of any general **dispersion formula** for determining the wavelength of a spectral line.

SPECTRUM, CONTINUOUS. Light or any other radiation may have such composition that, when analyzed with a **spectroscope,** it presents apparently an unbroken continuity of wavelength over a wide range. Such, for example, is the light from an ordinary lamp filament. Any incandescent solid, liquid, or gas under high pressure will radiate with a continuous spectrum. Sunlight appears to have a continuous spectrum until analyzed carefully, when the continuous spectrum is found to be crossed by a multitude of dark **Fraunhofer lines.** A continuous spectrum may extend without interruption from the extreme infrared to the extreme ultraviolet.

SPECTRUM, CONTINUOUS, FOR PARTICLES. A spectrum exhibiting a continuous variation in energy or momentum.

SPECTRUM, DARK-LINE. A **spectrum** which contains some lines darker than others, or than a continuous spectrum background. (See **Fraunhofer lines.**)

SPECTRUM, DIFFRACTION. The spectrum produced by **diffraction,** as may be produced by a **diffraction grating.** (See also **spectrum, normal.**)

SPECTRUM, DISCONTINUOUS. A term sometimes applied specifically to a combined band and line spectrum. (See **spectrum, band** and **spectrum, line.**)

SPECTRUM, DISCRETE. The same as **spectrum, line.**

SPECTRUM, EMISSION. The **spectrum (continuous, line or band)** produced by radiation from any emitting source, as distinguished from absorption spectra. (See **spectrum, absorption.**)

SPECTRUM, EXPLOSION. A **spectrum** obtained by the explosion of a solid or liquid substance, which shows lines of higher **excitation states.**

SPECTRUM, FINE. The resolution of lines in atomic emission spectra, by high-power spectroscopes, into two or more fine lines situated close together. The fine lines in atomic spectra arise from so-called term **multiplicities,** i.e., from transition between groups of higher, to groups of lower, levels, the levels comprising each group lying close together. Groups of close-lying levels are obtained by coupling the **orbital angular momentum vector** with the **spin angular momentum vector** of the atom in a variety of possible combinations.

SPECTRUM, FLAME. A spectrum of a substance obtained at the temperature of flame, commonly by maintaining a supply of the substance in the Bunsen flame. Because of the relatively low temperature and absence of high electrical potentials in most flames, flame spectra are best observed in relatively easily disassociated compounds, such as those of the first and second groups of the periodic table.

SPECTRUM, FLASH. See **flash spectrum.**

SPECTRUM, HYPERFINE. In the case of atomic emission spectra, there is, in addition to the fine structure (see **spectrum, fine**) of the spectral lines attributable to term multiplicities a hyperfine structure (fine lines very close together), which is attributable to a number of causes, including among others the isotope effect and the effect of the **spin** of the atomic nucleus. This spin couples with the total **angular** or **orbital momentum** of the nucleus and yields a series of resulting vectors representative of closely-spaced **energy levels.**

SPECTRUM, INFRARED. That region of the electromagnetic spectrum comprising radiations having wavelengths extending from the end of the visible red, at about 7.5×10^{-5} centimeters, to about 3×10^{-2} centimeters. The term infrared spectrum is also applied to a series of lines in this region obtained from a particular substance by resolution of its radiation, or by resolution of radiation transmitted through it, whereby dark lines are produced by absorption. The latter is called an infrared absorption spectrum.

SPECTRUM, INFRARED ABSORPTION (MOLECULAR). A spectrum produced by molecular absorption of radiations having wavelengths in the infrared region. These spectra depend, for their character and position, upon the energy changes involved, whether in vibrational energy, in rotational energy, or in combination. Their study furnishes considerable information about the groups and linkages in the molecule.

SPECTRUM LEVEL, SOUND PRESSURE. See **sound pressure spectrum level.**

SPECTRUM, LINE. (1) A spectrum produced by radiation in which the energy values of the property being measured, such as energy, mass, etc., cluster about one or more discrete values, in contrast with a continuous spectrum. A group of monoenergetic radiations is the result of identical quantum transitions of identical emitting-systems. There may exist a spread of energies about a mean value, giving a finite **line width** to the spectral line. Moreover, the actual width of a spectral line is often increased still further by instrumental imperfections. (2) A conventional name for the spectra of atoms as distinguished from **band spectra,** the spectra of molecules. Actually both types of spectra consist of lines.

SPECTRUM LOCUS. The locus of points representing the chromaticities of spectrally pure stimuli in a **chromaticity diagram.**

SPECTRUM, MAGNETIC. A term sometimes applied to particles (such as iron filings) spread out in a **magnetic field,** and distributed so as to show **lines of force.**

SPECTRUM, MAGNETIC RESONANCE. Spectra produced by absorption or emission of energy, commonly in the radio frequency region, by molecules which change their magnetic **quantum numbers** on absorption or emission of quanta of radiowaves. These spectra may be produced in a method developed by Rabi in which a molecular beam is sent through two inhomogeneous magnetic fields at right angles to it; between the two fields is a constant field, superimposed by a radiofrequency field, the resonance between these last two fields determining the magnitude of splitting of the energy levels. Other methods of observing magnetic resonance are similar in that they involve the superposition of a radio

frequency field on a steady or slowly varying magnetic field, about which the atoms precess. (See **Larmor precession.**)

SPECTRUM, MASS. A spectrum showing the distribution in mass or in mass-to-charge ratio of ionized atoms, molecules, or molecular fragments. The mass spectrum of an element shows the relative abundances of the isotopes of the element. The mass spectrum of a compound is quite complicated and not easily related to the relative abundances of the various kinds of atoms and groups present; however, under given experimental conditions it is characteristic of the compound and often useful for identification and assay.

SPECTRUM, MICROWAVE. A spectrum of wavelengths lying in the region between the far **infrared** and the conventional **radio-frequency** region. The boundaries of the microwave region have not been definitely fixed, but it is commonly regarded as extending from about 0.1 cm to 30 cm in wavelength, representing about 8 octaves of the electromagnetic spectrum.

SPECTRUM, MOLECULAR. The spectra of substances in the molecular state, like **atomic spectra,** are really made up of lines, though they are much more complicated. The transitions in a molecule which release the most energy (largest quanta) are due to electron changes, as in atoms, and the results of these changes are observed as lines in the **ultraviolet** region. But there are other ways in which a molecule can release or absorb energy. Thus the component atoms oscillate with reference to each other within the molecule, and this motion apparently is "quantized," i.e., changes abruptly from one state to another of different energy. (See **quantum theory.**) But these "vibrational" energy changes are much less than the electronic, so that the resulting quanta and spectrum lines are of much lower frequency, and appear in the extreme red or near **infrared.** Again, the molecule rotates, and the quantization of its rotational energy results in the emission of quanta of still lower frequency, appearing as lines in the far infrared.

Atomic spectra (due to electronic transitions) are characterized by series of lines progressively crowded together toward a "series limit." This is due to a variety of possible transitions of successively greater energy. The same is true of the changes in molecular rotational energy, but here the differences between the successive quantum energies are so very small and the lines are thus crowded so close together that a whole series of them appears merely as a "band," coming to a sharply defined edge on the low-frequency side and fading away gradually on the other side, or vice versa. Not only this, but the vibrational and electronic transitions are accompanied by rotational transitions, giving combined spectra which, on account of the close-grained character contributed by the rotational component, is composed of bands like the rotational bands themselves.

Thus a molecular spectrum appears as an array of bands instead of distinct lines, but arranged, like lines, in groups and series. The study of these bands and their groupings has furnished much information as to the structure and internal mechanism of molecules.

SPECTRUM, NORMAL. A term applied to the diffraction **spectrum,** because its dispersion is linear, which is not the case in a spectrum obtained from a prism.

SPECTRUM OF AN INCANDESCENT SOLID. In general, the spectrum of an incandescent solid is a continuous spectrum (see **spectrum, continuous**) but not a **black body** spectrum. (See **spectral energy distribution.**)

SPECTRUM OF THERMAL VIBRATIONS OF A SOLID (PHONON SPECTRUM). One of the prime problems of **lattice dynamics** is to establish the spectrum of the vibrational modes of crystals. The simplest approximation is that of Debye, who treated the crystal as a continuum, the atomicity being introduced by "cutting off" the distribution at a point where the number of modes equalled the number of degrees of freedom, $3N$. This was improved by Born and von Karman, who showed that there should be a cut off at a definite **wave-number,** the same for each of the different modes of polarization, and hence corresponding to different maximum frequencies for longitudinal and transverse modes. More detailed calculations, based on assumed interatomic force constants, have confirmed this general form of spectrum but no simple representation can be found. The spectrum fixes the **specific heat** as a function of temperature, and also such properties as **thermal**

conductivity, infrared and **Raman spectra,** etc.

SPECTRUM, PERSISTENT. The spectrum of a substance which results from the most moderate excitation. The most persistent of the lines have been called *raies ultimes*.

SPECTRUM, PRIMARY. The first-order spectrum produced by a **diffraction grating.**

SPECTRUM, RAMAN. A spectrum obtained by illuminating a substance with radiation, and obtaining from the radiations scattered at right angles a spectrum of those frequencies differing from the incident radiation. (See also **Raman effect.**)

SPECTRUM, REVERSAL. A spectrum which contains some lines darker than others, or than a continuous spectrum background. (See **Fraunhofer lines.**)

SPECTRUM, ROENTGEN. See **spectrum, x-ray.**

SPECTRUM, RESONANCE. A spectrum excited by the interaction with a substance (usually a molecular gas) of radiation of a definite frequency or frequencies. Thus in the early work, Wood studied the fluorescence of various molecular gases (e.g., Na_2 vapor) by exciting their resonance spectra by one of the intense lines of a mercury lamp or cadmium lamp. He found that only a single progression appears in this fluorescence spectrum, and not all the bands of the system, as resulting from excitation by white light. By excitation with another wavelength, in general, another series is obtained. Investigating the **fine structure** of such fluorescence bands, excited by a single line, Wood found them to consist, in general, of only a few lines. In the ideal case, when the illuminating line covers only a single absorption line, the "bands" consist either of only two lines, whose separation is approximately the same for the different bands, or sometimes of only a single line. Such series of "bands" are called resonance series; a spectrum excited in the way described is called a resonance spectrum.

With the advent of **quantum theory,** it became clear that the resonance spectrum results from the **excitation** of an atom from its **ground state** to an excited state by the absorption of radiation, and the subsequent emission of light during the return of the atom to the ground state.

SPECTRUM, SPARK. A spectrum produced by the passage of an electrical discharge, i.e., an electrical spark, commonly through a gas or vapor. (Spark discharges from metallic electrodes, at suitable potential, yield the spark spectra of the metallic vapors.) Variation of the applied potential has been found to change the character of the spark spectra obtained; the new series of lines observed at definite values of increasing potential are designated respectively as the first spark spectrum, the second spark spectrum, etc., those of higher numbers consisting of shorter wavelengths. These successive spectra represent progressive stages in the ionization of the atoms emitting them. (See also **spectrum, arc.**)

SPECTRUM, ULTRAVIOLET. The portion of the electromagnetic **spectrum** that begins at the end of the violet portion of the visible spectrum, at a wavelength of about 3900–4000 Ångström units, and consists of the radiations of decreasing wave length extending down toward the x-ray region to a wave length of about 200 Ångström units.

SPECTRUM, X-RAY. See **characteristic x-rays; continuous x-rays; crystal analysis; Mosely law.**

SPECULAR TRANSMITTANCE. See **transmittance.**

SPECULUM METAL. An alloy of tin (33%) and copper, capable of taking a very high polish. Especially used for reflection **gratings.**

SPEECH CLIPPING. The **clipping** of peak speech signals (peak clipping) or the reduction of weaker speech signals to zero (center clipping) in **intelligibility** tests.

SPEECH INVERTER. See **scrambler circuit; secrecy systems;** and **inverted speech.**

SPEECH POWER, AVERAGE. The average speech power for any given time interval is the average value for the instantaneous speech power (see **speech power, instantaneous**) over that interval.

SPEECH POWER, INSTANTANEOUS. The rate at which **sound energy** is being radiated by a speech source at any given instant.

SPEECH POWER, PEAK. The maximum value of the instantaneous speech power (see **speech power, instantaneous**) within the time interval considered.

SPEECH SCRAMBLER. See **scrambler circuit; secrecy systems;** and **inverted speech.**

SPEED. The magnitude of the vector **velocity.** Speed is a scalar quantity and is expressed in units of length divided by time.

SPEED, CRITICAL. The rotating parts of machines, such as shafts, armatures, etc., seldom have their masses distributed perfectly symmetrically about the axis of rotation. Hence **centrifugal forces** act on the mass; they are always in such a direction that they increase any asymmetry that may be present. The shaft, therefore, bends and this bending is opposed by elastic forces within the material. The presence of inertia and of restoring elastic forces insures that the shaft shall be an **oscillator** (2) with one or more resonance frequencies. As the speed is increased to the lowest resonance frequency, the amplitude of vibration becomes larger and it may reach a dangerously large value if the **damping** is small (see **oscillation, forced**). The speed at which this occurs is called the critical speed. Above the critical speed a state of equilibrium may again be attained in which the body virtually rotates about its mass center. Second, third, and fourth critical speeds are also possible but the amplitudes of the shaft vibration are progressively less

SPEED OF RESPONSE. See **time constant; dead time lag.**

SPHERE. See **spherical surface.**

SPHERE OF ATTRACTION OF MOLECULAR FORCES. The distance within which the mutual attraction of the molecules begins to have a "noticeable value"

SPHERE PHOTOMETER (INTEGRATING SPHERE PHOTOMETER). In order to measure the total light flux from a lamp, the intensity in each different direction would need to be measured. However, by putting the lamp near the center of a hollow sphere with perfectly diffusing white walls, the measurement of the intensity at one small window in the wall of the sphere is a measure of the total flux.

SPHERICAL ABERRATION. Exact calculation shows that a perfectly spherical surface, either reflecting or refracting, can never form a perfect image of a finite object. This defect, being caused by the geometry of a spherical surface, is hence called spherical aberration. The rays of light which make the largest angle with the optical axis will be the most influenced by this defect. Spherical aberration may be reduced by use of aspheric surfaces or, in the case of multiple element systems, by having the errors inherent to the different surfaces counteract each other. The reduction of spherical aberration to an acceptable amount is one of the first problems of the optical designer.

SPHERICAL ABERRATION, LATERAL. See **lateral spherical aberration.**

SPHERICAL ABERRATION, LONGITUDINAL. See **longitudinal spherical aberration.**

SPHERICAL-EARTH FACTOR. The ratio of the **electric field strength** that would result from **propagation** over an imperfectly-conducting spherical earth to that which would result from propagation over a perfectly-conducting plane.

SPHERICAL HARMONICS. See **harmonic.**

SPHERICAL POLAR COORDINATE. A **curvilinear coordinate system.** Its parameters are: (1) the **radius vector** r from an origin or **pole** to the point; (2) the colatitude θ, an angle made by r and a fixed axis, the polar axis; (3) the longitude ϕ made by the plane of θ with a fixed plane through the polar axis, called the meridian plane. The coordinate surfaces are: (1) concentric spherical surfaces about the origin, $r =$ const.; (2) right circular **conical surfaces** with apex at the origin and axis along the Z-axis, $\theta =$ const.; (3) planes from the Z-axis, $\phi =$ const. The range of the variables is $0 \leqq r \leqq \infty$; $0 \leqq \theta \leqq \pi$; $0 \leqq \phi \leqq 2\pi$. In terms of a right-handed rectangular system with the same origin

$$x = r \sin\theta \cos\phi; \quad r^2 = x^2 + y^2 + z^2$$

$$y = r \sin\theta \sin\phi; \quad \theta = \cot^{-1} z/\sqrt{x^2 + y^2}$$

$$z = r \cos\theta; \quad \phi = \tan^{-1} y/x$$

Synonymous terms are spherical coordinates or **polar coordinates** in space. If $\theta = \pi/2$, the point lies in the XY-plane and if the longitude ϕ is then called θ, as is customary,

the system becomes that of polar coordinates in a plane.

SPHERICAL SURFACE. A **surface** all points of which are at a fixed distance, the **radius,** from a fixed point, the **center.** The term **sphere** is frequently used for this surface but it more properly means a solid bounded by a spherical surface.

In rectangular coordinates its general equation is

$$x^2 + y^2 + z^2 + Gx + Hy + Kz + L = 0$$

but if the center is taken at the origin of the coordinate system, the equation becomes

$$x^2 + y^2 + z^2 = r^2$$

where r is the radius of the sphere.

SPHERICAL WAVE. See **wave, spherical.**

SPHEROID. See **ellipsoid.**

SPHEROIDAL COORDINATE. A degenerate system of **curvilinear coordinates** obtained from **ellipsoidal coordinates** when two axes of the quadric are equal in length. There are two special cases: **oblate** and **prolate** spheroidal coordinates.

SPHEROMETER. A measuring instrument used to determine the curvature of a spherical surface. The Geneva Lens Gauge consists of two fixed legs and a central movable leg which activates a dial gauge, and reads directly in **diopters.** Another type consists of a ring, which rests on the surface to be measured, and a central pin which indicates the curvature. Still another type has three fixed legs and a central, movable leg.

SPIDER. The highly-flexible perforated disk used to center the moving coil of a dynamic **microphone** or **loudspeaker** in the magnetic gap, without restricting its travel in and out of the gap.

SPIDER-WEB ANTENNA. See **antenna, spider-web.**

SPIN. To rotate about an axis. The term finds particular application in atomic and nuclear physics, where it is used to describe the **angular momentum** of **elementary particles** or of nuclei. It has been found that all such particles possess intrinsic angular momentum of amount $n\hbar/2$ where n is a small integer and $\hbar$ is the **Dirac** h. Their properties depend strongly on the magnitude of n. (See **fermion, boson, quantum statistics.**)

SPIN-DEPENDENT FORCE. Force between two particles which depends on their relative spin orientations and possibly on their spin directions relative to the line joining the particles. Physical basis could be the interaction between the magnetic moments of the particles, or in the case of nuclear forces, to the exchange of π-mesons between the nucleons.

SPIN, NUCLEAR. The total angular momentum of the atomic nucleus, when it is considered as a single particle.

SPIN QUANTUM NUMBER, ISOBARIC. See **quantum number, isobaric spin.**

SPINOR. It can be shown that the three-dimensional **rotation group** is isomorphic with a two-dimensional **unitary group,** but two matrix representations of the latter apply to every matrix of the former group. The abstract space described by the unitary matrices is called spin space and a **vector,** having two components in this space, is a **spinor** of first order. A **dyadic** in spin space is a spinor of second order. Such quantities, as suggested by their name, are useful in the quantum mechanics of particle **spin.**

SPINTHARISCOPE. An instrument in which **scintillations** are visually observed or counted through a magnifying lens system.

SPIRAL SCANNING. See **scanning, spiral.**

SPLASH RING. A shield placed in some **mercury-pool cathode tubes,** such as the **ignitron,** to prevent splashing of mercury onto the other electrodes

SPLIT-ANODE MAGNETRON. See **magnetron, split-anode.**

SPLIT HYDROPHONE. See **hydrophone, split.**

SPLIT PROJECTOR. See **projector, split.**

SPONTANEOUS. Occurring by virtue of inherent properties or energy as distinguished from processes carried out by deliberate application of external agency, as spontaneous evaporation, combustion, oxidation, etc.

SPORADIC E LAYER. See **ionosphere.**

SPORADIC REFLECTIONS. See **ionosphere;** and **abnormal reflections.**

SPOT. (1) The area instantaneously affected by the impact of an **electron beam** in a cathode ray tube. (2) One of the exposed regions on a **Laue photograph.**

SPRAY POINTS. A row of sharp points charged to a high d-c potential, the purpose of which is to charge and discharge the conveyor belt in a **Van de Graaff generator.**

SPREADING COEFFICIENT. A thermodynamic expression for the work done in the spreading of one liquid on another. It is the difference between the work of adhesion between the two liquids and the work of cohesion of the liquid spreading, which may be expressed by the equation

$$F_s = \gamma_B - \gamma_1 - \gamma_{1B}$$

where F_s is the spreading coefficient, γ_B is the **surface tension** of the stationary liquid, γ_1 is the surface tension of the spreading liquid, and γ_{1B} is the interfacial tension between the liquids.

SPREADING RESISTANCE. That part of the resistance of a **point contact rectifier** due to the bulk semiconducting material.

SPREADING, WORK OF. See **spreading coefficient.**

"SPROCKET TUNING." See **magnetron, tuneable, method of tuning.**

SPURIOUS PULSE MODE. See **pulse mode, spurious.**

SPURIOUS RADIATION. Any radiation from a transmitter other than that produced by the **carrier** and its normal **sidebands.** A radiated harmonic of the carrier is one example of a spurious radiation.

SPURIOUS RESPONSE. Output from a **receiver** due to a signal or signals having frequencies other than that to which the receiver is tuned. See **image response** as an example.

SPURIOUS TUBE COUNTS (IN RADIATION COUNTER TUBES). Counts in radiation **counter tubes** other than background counts and those caused by the source measured. Spurious counts are caused by failure of the quenching process, electrical leakage, and the like. Spurious counts may seriously affect measurement of **background counts.**

SPUTTER. In a **gas discharge,** material is removed, as though by evaporation, from the electrodes, even though they remain cold. This phenomenon is known as sputtering. The term is also used for the corresponding phenomenon when the discharge is through a liquid. In the first case, sputtering is a nuisance that limits the life of a device; in the second case, it is put to work to make colloidal solutions of metals.

SPUTTERING. A result of the disintegration of the metal **cathode** in a **vacuum tube** due to bombardment by positive **ions.** Atoms of the metal are ejected in various directions, leaving the cathode surface in an abraded and roughened condition. The ejected atoms alight upon and cling firmly to the tube walls and other adjacent surfaces, forming a blackish or lustrous metallic film. This effect is often utilized to form very fine-grained coatings of metal upon surfaces of glass, **quartz,** etc., purposely exposed to the sputtering. Films of different metals can be obtained by using cathodes made of these metals. Glass plates may be thus silvered, or suspension fibers of spun quartz rendered conducting for use in electrometers, etc.

SQUALL. A sudden, strong **wind** which may or may not be accompanied by a wind shift. Rain and snow squalls are showers accompanied by strong gusts

SQUALL LINE. Thunderstorms, rain showers or squalls, and snow showers or squalls often appear in a long line sometimes reaching hundreds of miles but only one **squall** in depth. Such lines of squalls or squall lines normally move perpendicular to their leading edge.

SQUARE FOOT UNIT OF ABSORPTION. See **sabin.**

SQUARE-LAW DEMODULATOR. See **demodulator, square-law.**

SQUARE WAVE. A wave which alternately assumes two fixed values for equal lengths of time, the time of transition being negligible in comparison with the duration of each fixed value.

A square wave requires a considerable number of sine-function frequencies to express it.

These components are not mere mathematical fictions but are true electrical components in the case of an electric wave. They may be separated and examined by means of proper filter circuits. Since a square wave will contain a long series of frequencies it may be used for rapidly determining the frequency response of a piece of equipment by applying the wave to the input and noting the distortion of the output wave. The distortion is due to certain frequencies of the original wave being attenuated or amplified out of proportion in passing through the circuit Thus the necessity of making a laborious series of tests at various frequencies using sine waves is avoided. When an operator is properly trained in interpreting the results of such testing, it offers a rapid means of checking amplifiers, networks, etc These square waves may be generated by a variety of electronic circuits.

SQUELCH. To automatically quiet a **receiver** by reducing its **gain** in response to a specified characteristic of the input

SQUIRREL-CAGE MOTOR. See **motor, electric.**

STABLE. See **stability.**

STABLE (OF AN ATOMIC OR NUCLEAR SYSTEM). Incapable of spontaneous changes; thus a stable **nuclide** is one that is not **radioactive.** The term is sometimes applied to nuclides for which radioactive transformations would be energetically possible, but are so highly forbidden as to result in radioactivity too feeble to detect by currently available techniques; thus nuclides with lifetimes exceeding about 10^{15} to 10^{18} yr would be considered stable at present. The term may be qualified to indicate incapability of a specified mode of spontaneous change; for example, β-stable means incapable of ordinary **β-disintegration,** although possibly capable of **α-disintegration, double-β disintegration, isomeric transition,** or **spontaneous fission.**

STABLE EQUILIBRIUM OF FLOATING BODY. A floating body is in stable or unstable equilibrium as the **metacenter** is above or below the **center of gravity.**

STABLE ORBIT (BETATRON, SYNCHROTRON). The circle of constant radius described by accelerated particles.

STABILITY. In general, the tendency to remain in a given state or condition, without spontaneous change; and thus that attribute of a system which enables it to develop restoring forces between its elements, equal to or greater than the disturbing forces, so as to restore a state of equilibrium between the elements. Thus, a body of air is in a stable state if, when displaced somewhat from its original position, it tends to return thereto. A chemical compound is said to be stable if it is not readily decomposed. In electricity and electronics, stability denotes the constancy of various characteristics of equipment; in **negative feedback systems,** the term means freedom from oscillatory tendencies. (See **stable [of an atomic or nuclear system]; stable orbit; equilibrium of forces; least energy principle; buoyancy; stability, mechanical.**)

STABILITY, CONDITIONAL. A condition of a **negative feedback** system which causes it to be stable (non-oscillating) for certain values of **gain,** and unstable for other values.

STABILITY FACTOR. In a **transistor** circuit, the ratio of the change in **collector current** to the change in I_{co} (d-c collector current for zero emitter current). In many circuits, this ratio is considerably greater than one, causing large changes in collector current as a function of temperature, due to the large temperature coefficient of I_{co} (11% per °C for germanium).

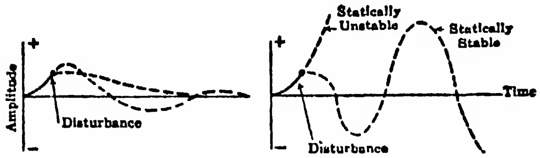
STABILITY, FREQUENCY. This term is commonly used to denote the accuracy with which the carrier frequency of a radio **transmitter** maintains a constant value. Various methods are used to improve this, among them being **crystal** control of the **oscillator,** electron coupling of the oscillator, high **Q,** tuned circuits, etc. (See also **frequency deviation.**)

STABILITY, MECHANICAL. A term for that property of a body which will cause it to develop forces in opposition to any position or motion disturbing influence. The subject may be divided into *static stability* and *dynamic stability.* The former is concerned with the production of the restoring forces, the latter with the oscillations that are set up in the system as a result of the restoring forces.

Another classification is into (1) *positive stability* when the displaced object returns to an initial state of equilibrium after a tem-

porary disturbance, (2) *neutral stability* when the object tends to remain in a definite position but when disturbed may come to rest in a new position, (3) *negative stability* (i.e., instability), when the object assumes an entirely new position when disturbed from its initial state. A simple damped pendulum illustrates the first; a sphere the second; while a slender cylinder standing vertically on end is a case of negative stability.

Let it be assumed that an object at rest or in a state of uniform motion receives a disturbing force. Depending on the kind of stability possessed, it might react with one of the motions shown in the accompanying figure. If it is dynamically stable as well as



Left: Positive stability (both statically and dynamically stable) *Right.* Negative stability (both dynamically unstable).

statically stable, its motion-time history may be one of diminishing oscillation or of simple subsidence, depending on the magnitude of damping, and inertial effects. Dynamic instability may occur with either static stability or static instability. These lead to divergent oscillation. or to complete divergence.

STABILIVOLT. A special type of **gas-discharge tube** used as a voltage stabilizer or regulator.

STABILIZED FEEDBACK. The name sometimes applied to **negative feedback.**

STACKING FAULT. A deviation from the correct order of stacking of the atomic planes in the construction of a **face-centered** cubic or **hexagonal close-packed** lattice.

STAGE EFFICIENCY. The ratio of useful power delivered to the load (alternating current) to the plate power input (direct current).

STAGGERED TUNING. In **superheterodyne receivers,** the peaking or resonating of each of the tuned circuits in an intermediate-frequency system to different frequencies. This is done to achieve a broad response.

STAGNATION POINT, FLUID FLOW. In inviscid flow, a point, usually on a bounding surface, at which the fluid velocity is zero with respect to the boundary. The flow around bodies of simple form (a sphere or a streamline body) has a forward and a rear stagnation point. A stagnation point in viscous flow may be defined as any point at which a streamline intersects either a boundary or another streamline.

STAGNATION PRESSURE. The pressure at a **stagnation point** in the flow. In effectively inviscid and irrotational flow, the **Bernouilli theorem** shows that the stagnation pressure is equal to the total head (see **head, total**) which is everywhere the same.

STAIRCASE GENERATOR. A generator whose output, as displayed on a linear time-base, •oscilloscope presentation, has the appearance of a staircase.

STALAGMOMETER. An apparatus for the measurement of **surface tension** by the drop-weight method. (See **surface tension, methods of measurement.**)

STAMPER. The negative image, usually chrome-plated for hardness, made from a master, which is used to make a phonograph record pressing

STANDARD CABLE. A theoretical cable used as a reference for specifying transmission losses. It has a linear series resistance of 88 ohms per mile, a linear shunt capacitance of 0.051 microfarads per mile with no inductance or shunt conductance.

STANDARD CELL. See **cell, standard.**

STANDARD CONDITIONS. For a gas, a temperature of 0°C (32°F) and a pressure of 1 standard atmosphere (see **atmosphere, standard (1)**). For a solid element, the allotropic form in which it most commonly occurs, and at ordinary temperatures, and at one atmosphere pressure.

STANDARD DEVIATION. The **root-mean-square** value of the deviations of a series of n like quantities X_j from their mean, $\bar{X}$. It is given by

$$\sigma = \left[\frac{\sum_{j=1}^{n}(x_j - \bar{x})^2}{n}\right]^{1/2}.$$

If the quantities X_i are distributed according to a Gaussian **error function,** the standard deviation bears a simple relationship to the **average deviation** and to the **probable error.**

STANDARD ENTROPY. See **entropy, standard.**

STANDARD ENTROPY OF IONS. See **ion(s), standard entropy of.**

STANDARD FREE ENERGY INCREASE. Often referred to as standard free energy. The increase in Gibbs free energy (see **free energy (1)**) when the reactants in a chemical change, all in their standard states (e g, unit concentration, or at one atmosphere pressure) are converted into the products in their standard states. Given by

$$\Delta G^{\circ} = -RT \ln K,$$

where R is the gas constant, T, the absolute temperature, K, the equilibrium constant. (See also **free energy change.**)

STANDARD FREE ENERGY OF IONS. See **ions, standard free energy of.**

STANDARD HEAT OF FORMATION. The heat required to form one mole of a compound from its elements in their standard state. The standard states for liquids and solids are usually taken as the stable forms at the atmospheric temperature and a pressure of 1 atmosphere.

STANDARD PITCH. See **pitch, standard.**

STANDARD OR UNIT PLANE. The **crystallographic** plane which has the **Miller indices (111).**

STANDARD PROPAGATION. See **propagation, standard.**

STANDARD STATE. The stable form of a substance at unit activity. The stable state for each substance of a gaseous system is the ideal gas at 1 atmosphere pressure; for a solution it is taken at unit mole fraction; and for a solid or liquid element it is taken at 1 atmosphere pressure and ordinary temperature.

STANDARD TELEVISION SIGNAL. See **signal, standard television.**

STANDARD VOLUME. The volume of one mole of a substance, in the form of a gas at a temperature of 0°C, and a pressure of 1 standard atmosphere (see **atmosphere, standard (1)**).

STANDARD VOLUME INDICATOR. A device for the indication of volume having the characteristics prescribed in the specification of the American Standards Association, ASA-C16.5. (See also **volume indicator.**)

STANDING CURRENT. Synonym for **quiescent** current.

STANDING WAVE. See **wave, standing.**

STANDING-WAVE INDICATOR. A traveling detector. (See **detector, traveling.**)

STANDING-WAVE LOSS FACTOR. The ratio of the **transmission loss** in an unmatched **waveguide** to that in the same waveguide when matched.

STANDING-WAVE PRODUCER. A movable **probe** introduced into a slotted **waveguide** to produce a required standing-wave pattern, usually for test purposes.

STANDING-WAVE RATIO. Any transmission line such as a **waveguide** or an acoustic transmission system, unless terminated by its **characteristic impedance,** will exhibit a superposition of standing and progressive waves. The standing wave ratio is a measure of the relative amplitudes of the two types of wave and is defined as the ratio of the maximum amplitude of pressure (or voltage) to the minimum amplitude of pressure (or voltage) measured along the path of the waves. Thus, at a given frequency in a uniform waveguide (see **waveguide, uniform**) the standing-wave ratio is the ratio of the maximum to the minimum amplitudes of corresponding components of the field (or the voltage or current) along the waveguide in the direction of propagation. Alternatively, the standing wave ratio may be expressed as the reciprocal of the ratio defined above.

STAR (NUCLEAR). A group of tracks due to ionizing particles originating at a common point, either in a nuclear emulsion or in a **cloud chamber,** so named because of its appearance. Some stars are produced by successive **disintegrations** of an atom in a **radioactive series;** others, by **nuclear reactions** of the **spallation** type, for example, by **cosmic-ray** particles.

STAR CONNECTION. This is the connection of the various phases of an a-c machine or circuit in which one end of all phases is connected to a common point, the other end of each phase going to a line. The **Y** is the three-phase star and is the most common example of this type connection.

STAR NETWORK. See **network, star.**

STAR RECTIFIER. See **rectifier, star.**

STARK EFFECT. The effect of a strong, transverse electric field upon the **spectrum** lines of a gas subjected to its influence. In many respects it resembles the more complicated types of **Zeeman effect,** but is subject to different laws, and may change radically in character and in multiplicity of component lines with increasing field intensity. The phenomenon, first observed by Stark in 1913, is conveniently studied by means of a **canal-ray** tube having behind the cathode a third electrode which may be given a high positive potential, in order to impose the desired field upon the radiating canal-ray particles.

STARK-EINSTEIN EQUATION. This equation, which is based on the **Stark-Einstein law,** gives the amount of energy absorbed in a photochemical reaction. It is of the form

$$E = Nh\nu$$

in which E is the amount of energy absorbed by one mole reacting, N is the **Avogadro constant,** h is the **Planck constant** and ν is the frequency of the radiation. Since N and h are constants, E is a function only of the frequency. This quantity E for a given wavelength is frequently referred to as one einstein unit of radiation.

STARK-EINSTEIN LAW. Each molecule taking part in a chemical reaction induced by exposure to light absorbs one quantum of the radiation causing the reaction.

STARK-LUNELUND EFFECT. The polarization of light emitted by a beam of moving atoms in the absence of a field

STARTER (OF A GLOW-DISCHARGE COLD-CATHODE TUBE). An auxiliary electrode used to initiate conduction.

STARTER BREAKDOWN VOLTAGE (OF A GLOW-DISCHARGE COLD-CATHODE TUBE). The starter voltage required to cause conduction across the starter gap with all other tube elements held at cathode potential before **breakdown.**

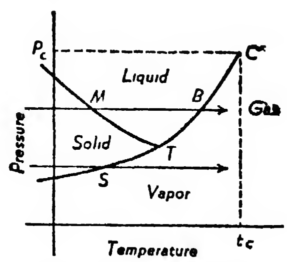
STARTER GAP (OF A GLOW-DISCHARGE COLD-CATHODE TUBE). The conduction path between a starter and the other electrode to which starting voltage is applied.

STARTER VOLTAGE DROP (OF A GLOW-DISCHARGE COLD-CATHODE TUBE). The starter-gap voltage drop after conduction is established in the **starter gap.**

STAT-. A prefix used to indicate that electrical quantities are expressed in the electrostatic system of units. This prefix is employed before the names of units in the practical system, e g., statvolt, statoersted. (See **esu system of units; INTRODUCTION.)**

STATE. In its fundamental connotation, this term refers to the condition of a substance, as its state of aggregation, which may be solid, liquid, or gaseous—massive or dispersed. As extended to a particle, the state may denote its condition of **oxidation,** as the state of oxidation of an atom, or the **energy level,** as the orbital of an electron, or in fact, the energy level of any particle.

STATE(S) OF MATTER. The solid, the liquid and the gaseous state which for any pure substance, are determined by two variables, temperature and pressure, with the density as a third, related variable. If the temperature and pressure are under complete control, it is possible to pass from any one to any other of the three states, either directly by a single transition, or by passing through the third state with two transitions. This will be clear from the accompanying phase diagram,



Temperature-pressure curves for substance like water. C represents the critical state, T the three-phase equilibrium point

which represents the temperature-pressure equilibrium curves, for a substance converging at the **three-phase equilibrium** or "triple

point" T. (It is understood that each phase of the substance is to be strictly pure; for example, no air is to be mixed with the vapor.) Thus, if a mass of pure ice were kept completely enclosed by itself at a fixed pressure below 4.6 mm (its "triple point"), and its temperature raised, it would turn directly into vapor at the **sublimation** point S; but if the pressure exceeded 4.6 mm, the ice would first become liquid at the **melting point** M, and the water would then vaporize at the **boiling point** B, corresponding to the existing pressure. The volume of the enclosure would, of course, have to be varied to keep the pressure constant during these changes.

When the temperature has exceeded the critical temperature t_c (see **critical state**), neither the solid nor the liquid phase can continue to exist, even with increased pressure. The liquid-vapor curve must be considered as terminating at C, since it pertains specifically to two phases in equilibrium, while beyond the point C the substance does not exhibit two phases. The one apparently homogeneous phase now remaining is said to be a true "gas."

STATE, STEADY. A condition of dynamic balance, as in an **equilibrium** reaction, where at equilibrium the concentration of each of the reactants remains constant. In such cases the loss of reactants to form products just balances the formation of reactants from the products in the reverse reaction. A physical system is said to be in a steady state if the various quantities describing the system are either independent of time or are periodic functions of time. Thus an **alternating current circuit** is in a steady state after all **transient** effects of a disturbance have disappeared.

STATE VECTOR. Vector in **Hilbert space** describing the state of a dynamical system, particularly in quantized field theory. (See **field theory, quantized.**)

Thus having specified all possible momentum states of the various particles which may be present, the state vector may prescribe which of these states are occupied, and by how many particles, in a given physical situation.

STATIC. The name commonly applied to all the various random electrical disturbances which are picked up by a radio **receiver.** These can be divided into two general classes, natural and man-made static. The first is caused by various types of natural electrical discharges, the most pronounced being those of lightning. However, a static-producing discharge is not necessarily, or even usually, a visible lightning discharge. Various static charges are often continually building up and discharging in the atmosphere and hence inducing disturbances in the receiver. Cosmic radiations are also responsible for static. These types of natural static are often called atmospherics. The types of man-made static are almost as numerous as the electrical machines which man has developed. Any sparking contact or poor electrical connection will produce static which will be picked up by nearby receivers. Unfortunately many types of this interference may be fed back along the power lines and directly into the receiver. **X-ray** and diathermy machines are also sources of interference but cannot be properly classed as static.

The elimination of static presents a particularly difficult problem since the frequencies in the static pulse cover a wide band, certain types being more prevalent in some frequency ranges than others. Man-made static is best eliminated by correcting the fault at the source although a **filter** in the power line often helps if the disturbance is coming into the set through the line. Natural static can be minimized, but not eliminated. For amplitude **modulation** systems, limiting the **frequency band** to which the receiver responds will reduce the noise. Various types of limiters will also reduce the effect since the static signal is frequently greater than the desired one. Frequency modulation is inherently less susceptible to interfering noise and offers almost noise-free reception.

STATIC CHARACTERISTIC (OF AN ELECTRON TUBE). A relation, usually represented by a graph, between a pair of variables such as electrode voltage and electrode current, with all other voltages maintained constant.

STATIC ELECTRICITY. See **electrostatics.**

STATIC EQUILIBRIUM. See **equilibrium of forces.**

STATIC FREQUENCY TRANSFORMER. See **frequency transformer.**

STATIC MACHINES. A variety of devices have been employed to furnish charges of electricity of considerable quantity at high voltage. Probably the simplest static machine is the **electrophorus,** operating on the principle of electric induction, but its output and voltage are quite limited. Some of the older machines generated charges by friction, but modern machines are of the induction type. Among the latter, the well known Toepler-Holtz and Wimshurst machines have rotating glass or mica plates bearing metal "carriers" on which the charges are induced as on the metal plate of the electrophorus. Recently some very powerful induction machines, embodying all the principles of the older types, have been developed by Van de Graaff and others and have come into use in nuclear research.

STATIC METHOD. See **vapor pressure, methods of measurement.**

STATIC PRESSURE. (1) In a fluid, the pressure as measured by an observer moving with the fluid In practice, the pressure observed by inserting in the flow a properly aligned static pressure tube This is a tube pointing into the flow, sealed at the forward end and communicating with the flow by a ring of holes some six diameters from the end. (2) For static pressure in acoustics, see **pressure, static.**

STATIC REACTION. The static **force** exerted on a body by other bodies by which it is supported in **equilibrium.**

STATIC SOUND PRESSURE. See **pressure, static.**

STATIC STATE. In meteorology, a state in which the position or properties of an **air mass** or frontal zone are not changing or moving, such as a "static front" or "static conditions."

STATICS. Statics is that branch of mechanics which deals with particles or bodies in **equilibrium** under the action of **forces** or of **torques.** It treats of the composition and resolution of forces, the equilibrium of bodies under balanced forces, and such properties of bodies as center of gravity and moment of inertia.

A set of forces may be exerted along lines which all lie in the same plane, in which case they are said to be coplanar. Again, the lines of action may all intersect at one point, so that the forces are "concurrent." A torque, or moment, is that which tends to produce rotation about some axis. The measure of the torque of a given force about an axis not parallel to its line of action is the product of the force, the perpendicular distance from its point of application to the axis, and the sine of the angle between the axis and the direction of the force Two forces of equal magnitude, acting along parallel lines in opposite directions, constitute a couple, the torque of which, about any axis perpendicular to its plane, is the product of either force by the perpendicular distance between their lines of action. Such a pair of forces has no resultant and no equilibrant, since it can neither be replaced nor balanced by a single force It is possible to have a system of more than two forces, not necessarily parallel or even coplanar, but which is equivalent to a couple in that it has a torque without having a resultant. Only another couple, or its equivalent, can balance such a system. One of the basic propositions of statics is that any system of forces is, in general, equivalent to a single force acting along a definite line and a couple whose torque axis is in a definite direction; and that for equilibrium, this force and this couple must both become zero These ideas are most conveniently expressed by means of the notation of vector analysis

A force F, whose line of action lies at θ degrees to one of two mutually perpendicular axes, may be resolved into components of $F \cos \theta$ and $F \sin \theta$, parallel to the axes. When several forces are concurrent, and coplanar as well, the components of their resultant are found as the algebraic sums of the components of the separate forces The resultant of two coplanar forces P and Q having an included angle θ, has a magnitude

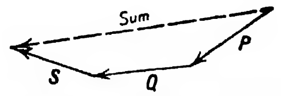
$$R = \sqrt{P^2 + Q^2 + 2PQ \cos \theta}.$$

The angle between the resultant and the force P is

$$\arc \tan \frac{Q \sin \theta}{P + Q \cos \theta}.$$

If there are more than two forces whose resultant is to be found, any two may be combined to find the resultant which may then be combined with a third, and so on until the last resultant found is that for the complete array of forces. The same problem may be solved

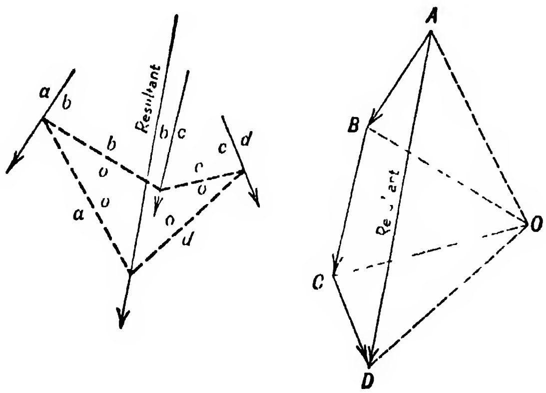
graphically by the vectorial addition of the forces. In vectorial addition, lines whose lengths are equal to the magnitudes of the forces are drawn in the directions of the forces



Vectorial Addition of Forces P, Q, & S

Fig 1

so that the force representing one line follows another, forming part of a polygon, the arrows of which, as shown in Fig. 1, are in succession. The resultant is the line drawn from the beginning of the first force to the end of the last. This resultant force, with direction of arrow reversed, is the equilibrant, or neutralizing force. When forces are concurrent, the line of application of the resultant is known to pass through the point of concurrence of the forces; but with non-concurrent forces, neither the force polygon nor the analysis by components is sufficient to establish the line of application of the resultant force. To locate this line, another condition of statics must be introduced. It is that the moment of the resultant about any moment axis is equal to the algebraic sum of the moments of the forces about the same axis. The **funicular polygon** may also be used to establish the line of action of non-concurrent forces (see Fig. 2). Rays



Forces in space Force polygon

Fig. 2. Funicular polygon

are drawn to the corners of the force polygon from some assumed pole, and the sides of the funicular polygon drawn parallel to these rays. The corners of the funicular polygon lie on the forces themselves, and the closing lines, *oa* and *od*, intersect on the line of action of the resultant. (See **Bow notation.**)

When forces are not coplanar, the solution, in general, involves simultaneous solution of six equations, as follows:

Let F_x, F_y, and F_z be components parallel to x, y, and z axes, respectively.

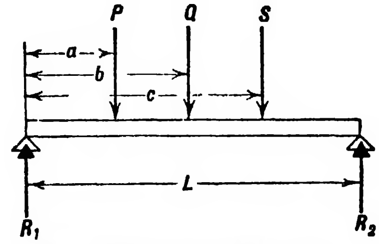
R_x, R_y, R_z are the corresponding components of the resultant.

$$\Sigma F_x = R_x,$$
$$\Sigma F_y = R_y,$$
$$\Sigma F_z = R_z,$$
$$\Sigma M_{Fx} = M_{Rx},$$
$$\Sigma M_{Fy} = M_{Ry},$$
$$\Sigma M_{Fz} = M_{Rz}$$

in which the M's are the moments of the respective components about either axis perpendicular to them.

Static equilibrium exists if the algebraic sum of the components of the forces in any direction is zero, and if the algebraic sum of the moments of the forces about any axis is zero. When a body is in equilibrium under forces, some of which are unknown, an analysis may be made by applying these conditions of equilibrium, provided that, of the quantities required to specify the forces, the number which are unknown does not exceed the number of equations afforded by the given conditions. In the graphical analysis of static equilibrium, the conditions of equilibrium are that the force polygon and the funicular polygon close.

A common application of the laws of equilibrium of coplanar forces is the calculation of the reactions of a simply supported beam loaded with parallel forces which are perpendicular to the length of the beam. The reactions are determined by considering the whole system to be one in equilibrium, so that the moment equation may be applied by selecting the moment center on one of the un-



Beam loaded with parallel forces

Fig. 3

known reactions. The moment of this reaction thus becomes zero, and the moment equation has only one unknown reaction. If a beam of span L (Fig. 3) is loaded with forces P, Q, and S, at distances, a, b, and c from R_1, the sum of the moments equals

$$R_2L - Pa - Qb - Sc.$$

For equilibrium, this quantity must equal zero; hence

$$R_2 = \frac{Pa + Qb + Sc}{L}.$$

Triangularly framed structures may be analyzed by algebraic resolution and composition of forces, or by the graphical method of funicular and force polygons. Since the latter is simpler and entirely as useful, it is the one most frequently employed. Consider a simple derrick, framed as shown in Fig. 4, loaded

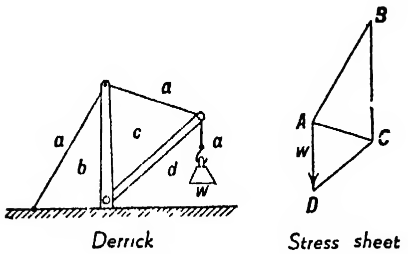


Fig 1

with weight W. This condition of static equilibrium may be analyzed for the forces acting in the structural members by drawing a force polygon for each joint, beginning with that which has only two forces unknown in magnitude, then proceeding to some other joint, where the same condition exists. In the example given, it is plain that the joint at the load must be analyzed first. The equilibrium polygon for this joint is CDA, and is drawn by laying off DA in the direction of W, and of the magnitude W, and locating point C as the intersection of lines DC and AC, drawn in the directions which those forces actually have in the derrick. Using the magnitude of CA thus determined, the joint at the top of the mast may next be analyzed, locating the point B. The magnitudes and character of the forces acting on triangularly framed structures are thus determined by the method of analysis of joints graphically by force polygons which close. These force polygons begin at a point where all corners of the polygon are known except one, and proceed from there in succession to other joints, which will offer the same conditions. Each joint has a separate force polygon, but it is usual to place these polygons in juxtaposition along the lines where they have lines in common, for convenience and simplification. The resulting diagram, which is a composite force polygon, is known as a stress diagram or stress sheet.

Certain cases of **friction** lie properly in the realm of statics, since, though the friction may be that of moving bodies, the frictional surfaces themselves may not be in relative motion. Friction gearing, wedges, friction clutches, and the general problem of the inclined plane which includes the screw jack are typical examples. Friction is resistance offered by one body to the motion of another when the second body slides, or tends to slide, over the former. A normal force between two surfaces, which have a coefficient of friction f, results in a force fN opposing motion, where N is the normal force. This friction force is tangent to the surfaces of contact in a direction which would oppose motion The resulting force, acting between a body and its supporting surface, takes the direction shown in Fig. 5. The horizontal component of the

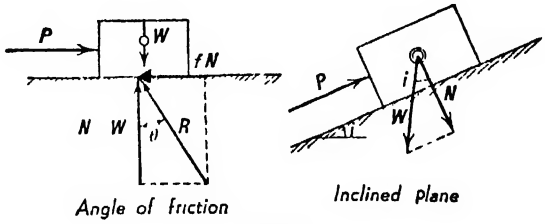


Fig 5

reaction R is equal to P. As P increases up to the point of sliding, the angle θ increases until its tangent equals the coefficient of friction of the surfaces in contact. When P exceeds fN there will be relative motion between the body and the supporting surface. Should a body having weight W rest on a plane inclined at angle i, the coefficient of friction between the surfaces being f, the force necessary to start the body up the plane must be greater than $W \sin i + fW \cos i$ where the force P is parallel to the plane. If the force P is inclined to the plane, only its component parallel to the plane will be available for starting the load, and its perpendicular component may either tend to increase or decrease the friction resistance.

The centers of gravity of areas and masses

come under the head of statics, since they may be considered as made up of a number of elementary areas or masses, which could be treated as proportional to a set of parallel forces acting through their individual centers.

STATION, CLASS I, II, ETC. See under **Class I station,** etc.

STATIONARY CPA AXIS. A fixed-reference phase with respect to which a **carrier color signal** of constant **chrominance** makes equal and opposite angles for successive fields; this reference phase being the same for all chrominances.

STATIONARY STATE. One of the discrete energy states in which a quantized particle or system (e.g., an electron, atom, molecule, etc.) may exist, according to the **quantum theory.**

STATIONARY WAVES. See **wave, standing.**

STATISTICAL MECHANICS. One major problem of physics involves the prediction of the macroscopic properties of matter in terms of the properties of the molecules of which it is composed. According to the ideas of classical physics, this could have been accomplished by a determination of the detailed motion of each molecule and by a subsequent superposition or summation of their effects. The Heisenberg **indeterminacy principle** now indicates that this process is impossible, since we cannot acquire sufficient information about the initial state of the molecules. Even if this were not so, the problem would be practically insoluble because of the extremely large numbers of molecules involved in nearly all observations. Many successful predictions can be made, however, by considering only the average, or most probable, behavior of the molecules, rather than the behavior of individuals. This is the method used in statistical mechanics.

In the general approach to classical statistical mechanics, each particle is considered to occupy a point in **phase space,** i.e., to have a definite position and momentum, at a given instant. The probability that the point corresponding to a particle will fall in any small volume of the phase space is taken proportional to the volume, and the probability of a specific arrangement of points is proportional to the number of ways that the total ensemble of molecules could be permuted to achieve the arrangement. When this is done and it is further required that the number of molecules and their total energy remain constant, one can obtain a description of the most probable distribution of the molecules in phase space. The **Maxwell-Boltzmann distribution law** results.

When the ideas of symmetry and of **microscopic reversibility** are combined with those of probability, statistical mechanics can deal with many steady state problems as well as with equilibrium distributions. Equations for such properties as viscosity, thermal conductivity, diffusion, and others are derived in this way.

The development of **quantum theory,** particularly of **quantum mechanics,** forced certain changes in statistical mechanics. In the development of the resulting **quantum statistics,** the phase space is divided into cells of volume h^f, where h is the **Planck constant** and f is the number of **degrees of freedom.** In considering the permutations of the molecules, it is recognized that the interchange of two identical particles does not lead to a new state. With these two new ideas, one arrives at the Bose-Einstein statistics. These statistics must be further modified for particles, such as electrons, to which the Pauli exclusion principle applies, and the Fermi-Dirac statistics follow.

It is often possible to obtain similar or identical results from statistical mechanics and from **thermodynamics,** and the assumption that a system will be in a state of maximal probability in equilibrium is equivalent to the law of **entropy.** The major difference between the two approaches is that thermodynamics starts with macroscopic laws of great generality and its results are independent of any particular molecular model of the system, while statistical methods always depend on some such model.

STATISTICAL METHOD OF ENTROPIES. A method performed using **partition functions** from assumed molecular models or spectroscopic data. The relation used is

$$S = R \ln Z - R \frac{\partial(\ln Z)}{\partial(\ln \beta)}$$

where S is the entropy, R the gas constant, Z the partition function, and $\beta = 1/kT$ (k being the Boltzmann constant, T, the absolute temperature).

STATISTICAL WEIGHT FACTOR. In the statistical investigation of a given quantity, a **statistical weight** can be assigned to each value or range of values of the quantity, which is the number of times this value or range of values occurs. In statistical mechanics, it is defined as the number of microstates corresponding to a given macrostate.

STATISTICS. This term is used in two related senses. In the first, it applies to the combination of data obtained from individual events or from separate entries of events. See **error** and the following entries for the application of statistics to the determination of **uncertainties.** The second sense of the word denotes the distribution laws which result from **statistical mechanics.** (See also **quantum statistics; Maxwell-Boltzmann distribution law.**)

STATOR. The stationary portion of a **dynamo.**

STEADY STATE. See **state, steady.**

STEADY-STATE OSCILLATION. See **oscillation, steady-state.**

STEADY-STATE VIBRATION. See **oscillation, steady-state.**

STEAM. (1) Water vapor, especially when at a temperature at or above the boiling point of water. (2) By analogy, the vapor of any liquid at or above the boiling point of the liquid.

STEAM DISTILLATION. The process whereby compounds which are sparingly soluble in water may be distilled by heating with water or by blowing steam through the mixture. Compounds of relatively high boiling point may be distilled at lower temperatures by this method.

STEEPEST DESCENT, METHOD OF. An approximate method of evaluating **integrals** of the form

$$I = \int_t^b g(z)e^{tf(z)}dz$$

where t is large, real and positive and $f(z)$ is **analytic.** The path of integration is chosen so that it passes through a **saddle point** z_0. Then if $(z - z_0) = re^{i\alpha}$, the integral is given asymptotically by

$$I \sim \frac{g(z_0)e^{tf(z_0)+i\alpha}\sqrt{2\pi}}{|tf''(z_0)|^{1/2}}.$$

The procedure is sometimes used to evaluate integrals occurring in **statistical mechanics.**

STEERABLE ANTENNA. See **antenna, steerable.**

STEFAN-BOLTZMANN LAW. The total radiation from a **black body** or complete radiator is given by

$$E = \sigma T^4$$

where T is the absolute temperature and $\sigma = 5.672 \times 10^{-5}$ erg cm^{-2} deg^{-4} sec^{-1}. Sometimes called the "Fourth Power Law." This law may be obtained by integration of the **Planck distribution law,** but was known before the distribution law was developed.

STEINMETZ COEFFICIENT. Steinmetz approximated **hysteresis loss** by the expression $aB_m^{1.6}$, where B_m is the maximum **induction,** and the Steinmetz coefficient, a, is constant for a given material.

STELLAR INTERFEROMETER. An attachment for astronomical telescopes by which Michelson was first able to measure the angular diameters of certain stars.

STEM CORRECTION. A correction to be made in the reading of a thermometer which has part of its stem containing a portion of the thermometric-fluid column outside the region at the temperature being measured, so that amount of the thermometric fluid is not at the correct temperature.

STENODE CIRCUIT. An intermediate-frequency **amplifier** whose selectivity has been increased by a **piezoelectric-crystal** filter.

STERADIAN. A unit **solid angle,** which encloses a surface on a sphere equivalent to the square of its radius. The total solid angle about a point equals 4π **steradians** since the area of a sphere of unit radius equals 4π.

STEREO-CEPHALOID MICROPHONE. A plurality of microphones arranged within a structure designed to produce diffractions and acoustic pickup patterns simulating normal human hearing.

STEREO-LOUDSPEAKER. A loudspeaker system consisting of two or more loudspeakers placed in two or more locations, and which can be energized by a stereophonic amplifier system so as to produce a stereophonic effect.

STEREO-MICROPHONES. Two or more microphones so spaced apart and connected to a stereophonic amplifier as to enable stereophonic recording or reinforcement.

STEREOPHONE. An acoustical system in which a plurality of **microphones** (or other **transducers**), **transmission channels** and **reproducers** are arranged so as to provide a sensation of spatial distribution of the original sound sources to the listener.

STEREOPHONIC. Pertaining to or adapted to the **stereophone**; produced by the stereophone, as stereophonic magnetic tape recordings, stereophonic sound system, stereophonic reproduction.

STEREOPHONICALLY. In a **stereophonic** manner; by means of stereophonic equipment.

STEREOPHONICS. The science which treats of the recording, reinforcement, or reproduction of sound in such a manner as to provide a sensation of spatial distribution of the original sound sources.

STEREOPHONISM. The state of being **stereophonic.**

STEREOPHONISM, COMPRESSED. The condensation of a wide acoustic field into a narrow area. It occurs when a 100-piece orchestra spread across a 50-foot stage is played back to sound as though it were coming from a 10-foot stage.

STEREOPHONISM, CROSSED. Sources originally in the right field are heard in the left ear and vice versa. (In headphone stereophony crossing earphones produces the effect.)

STEREOPHONISM, DIFFUSED. The production of the effect of spreading point sources (see **source, simple point**) of sound, characterized by loss of precise **localization.**

STEREOPHONISM, DIPHONIC. The production of two **localizations** for a single sound source.

STEREOPHONISM, EXPANDED. The opposite of compressed stereophonism. (See **stereophonism, compressed.**)

STEREOPHONISM, MULTIPHONIC. The production of multiple **localization** of a single sound source.

STEREOPHONISM, REFLECTIVE. A condition occurring when **stereophonic** effects are diminished or lost because of excessive reflection during pickup or reproduction.

STEREOPHONISM, REVERBERATORY. A condition occurring when **stereophonic** effects are diminished or lost because of excessive **reverberation** during pickup or reproduction.

STEREOPHONY. The art of using, designing, or manufacturing **stereophonic** equipment.

STEREOPHONY, HEADPHONE. The art of producing **stereophonic** effects with headphones.

STEREOPHONY, LOUDSPEAKER. The art of producing **stereophonic** effects with **loudspeakers.**

STEREOPHONY, MULTI-CHANNEL. The art of producing **stereophonic** effects with more than two electrical **transmission channels.**

STEREO-POWER. For prism binoculars or similar stereo systems, the ratio of the distance between the objective axes to the distance between eyepiece axes multiplied by the magnifying power. A measure of the **stereoscopic radius.**

STEREOSCOPE. The sensation of depth in an object is due to binocular vision; that is, to the fact that two eyes do not each see exactly the same view. By taking two pictures with a camera moved a few inches—or with a double stereoscopic camera—two slightly different pictures are obtained. A stereoscope is a device by which each eye sees only one of these pictures, and the same sensation of depth is obtained as with direct **binocular vision.**

STEREOSCOPIC RADIUS. The greatest distance at which the stereoscopic effect (see **stereoscope**) can be perceived. For unaided eyes, it has been given as about 1500 ft; with prism binoculars, it is of course greater.

STEREOSPECTROGRAM. A method of representing spectral data in which the three variables, concentration of solute, **optical density,** and wavelength of light, are plotted in three dimensions to produce a three-dimensional figure; or else in two dimensions by choosing an oblique axis in addition to the customary x-axis and y-axis.

STERIC-FACTOR OR PROBABILITY FACTOR. A correction factor applied, in cases of many "slow" reactions, to correct the values calculated for the reaction rates by the collision theory. It is believed that the reason for the discrepancy, or, in other words, the physical meaning of the steric factor, may be the large number of **degrees of freedom** in which energy transformations must occur, in certain reactions, to form the **activated complex.**

STERIC HINDRANCE. The effect of the spatial arrangement of the atoms in the structure of a molecule in retarding a chemical reaction or process.

STERN-GERLACH EXPERIMENT. An experimental test by O. Stern and W. Gerlach (Germany, 1924) of the magnetic moment of atoms. A stream of metallic atoms, issuing from a vaporizing furnace through a narrow

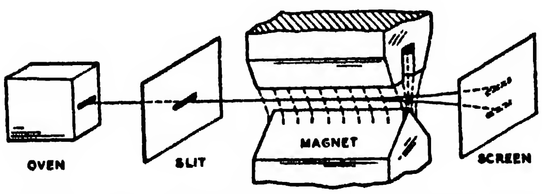


Diagram of Stern-Gerlach experiment for determining magnetic moments of gaseous atoms Beam of vaporized metal is split by strong inhomogeneous magnetic field (By permission from 'Ferromagnetism" by Bozorth, Copyright 1951, D Van Nostrand Co, Inc.)

slit, entered a strong magnetic field. The magnetic intensity was perpendicular to the atom stream, and had a strong gradient in its own direction. If magnetic moments of atoms are due to revolving electrons, the atoms should, according to classical theory, begin to precess at all angles about the field direction, and the atomic beam should simply broaden into a band. According to the quantum theory, they should precess at certain angles only, and the original stream should be divided into distinct streams. Since the beam was split into $2J + 1$ different beams, the experiment showed that in a magnetic field not all orientations to the field, but only $2J + 1$ discrete directions, are possible.

STETHOSCOPE. A device for increasing the sound transmission from the interior of the human body to an observer's ear. It consists of a shallow chamber of relatively large diameter connected to a long tube of small diameter. The chamber serves to improve the acoustic matching between the body tissue and the air in the narrow tube.

STEWART-HOVDA RELATIONSHIP. See **binaural intensity effect.**

STICKING POTENTIAL. See **potential, sticking.**

STICTION. Static **friction.**

STIFFNESS. In general the ability of a system to resist a prescribed deviation. In the case of a **deformable elastic medium,** stiffness is the ratio of a steady force to the **elastic displacement** produced by it, e g, for a spring the force required to produce unit stretch The term is applied most often to an elastic system vibrating about a position of equilibrium. Acoustic stiffness is the quantity which, when divided by 2π times the frequency, gives the acoustic reactance (see **reactance, acoustic**) associated with the potential energy of the medium or its boundaries. The unit commonly used is dyne/cm. Mechanical stiffness is expressed in terms of the various **elastic moduli.**

STIFFNESS COEFFICIENT. In a linear mechanical system, the ratio of the applied force to the displacement from equilibrium.

STIFFNESS CONSTANTS. See **elastic moduli.**

STIFFNESS ELEMENT, ACOUSTIC. Any **acoustical element** that makes a contribution to the acoustical equation of motion analogous to the contribution of the stiffness of a spring in a mechanical system.

STIGMATIC. (1) For a bundle of rays, **homocentric.** (2) For an optical system, having equal **focal power** in all meridians.

STILB. A unit of brightness of a surface equal to 1 **candle/cm^2.**

STIRLING FORMULA. If n is a large number

$$\ln n! = \left(n + \frac{1}{2}\right) \ln n - n + \frac{1}{2} \ln 2\pi + \frac{1}{12n} - 0(1/n^3),$$

where the last term is of the order of $1/n^3$. Often approximated by: $\ln n! = n \ln n - n$

STIRLING FORMULA FOR INTERPOLATION. Useful near the middle of a **difference table** in finding a value of the dependent variable y at a value of the independent variable $x = x_0 + hu$, where h is the interval between equally-spaced values of x The formula involves **central differences**

$$y = y_0 + \mu\delta y_0 u + \delta^2 y_0 \frac{u^2}{2!} + \mu\delta^3 y_0 \frac{u(u^2 - 1)}{3!} + \cdots$$

$$\mu\delta y_0 = \tfrac{1}{2}(\Delta y_0 + \Delta y_{-1});$$

$$\mu\delta^3 y_0 = \tfrac{1}{2}(\Delta^3 y_{-1} + \Delta^3 y_{-2}); \cdots$$

$$\delta^m y_0 = \Delta^m y_{-m/2}.$$

STIRLING NUMBER. If the nth degree **polynomial** $f(x) = x(x-1)(x-2) \cdots (x - n + 1)$ is written in the form $f(x) = S_0^n x^n + S_1^n x^{n-1} + \cdots + S^n_{n-1} x$ the numerical coefficients S_i^n are known as **Stirling numbers.** They may be calculated successively from the **recursion formula** $S_i^{n+1} = S_i^n - nS^n_{i-1}$.

STOICHIOMETRIC. Having the exact proportions of elements to make a pure chemical compound.

STOKE. The cgs unit of kinematic viscosity. (See **viscosity, kinematic.**)

STOKES DRIFT (OF GRAVITY WAVES). Stokes showed that, although the motion at any point in a gravity wave of finite amplitude is periodic, the **particle velocities** are periodic with a non-zero mean. There is thus a drift velocity of particles in the direction of motion of the wave.

STOKES LAW METHOD. See **viscosity, measurement of.**

STOKES LAWS. (1) The force required to propel a spherical body of radius r at uniform speed v through a viscous medium of viscosity ν is $6\pi\nu v r$. (2) The wavelength of **luminescence** excited by radiation is always greater than that of the exciting radiation. (See **antistokes lines.**)

STOKES LINE. A spectral line which satisfies **Stokes law** by having a wavelength greater than that of the radiation which excited the luminescence of the source.

STOKES THEOREM. The **surface integral** of the **curl** of a **vector function** equals the **line integral** of that function around a closed curve bounding the surface

$$\int_S \nabla \times \mathbf{V} \cdot d\mathbf{S} = \oint \mathbf{V} \cdot d\mathbf{S}.$$

If the components of $\mathbf{V}$ in rectangular Cartesian coordinates are u, v, w and the **direction cosines** of the normal to $d\mathbf{S}$ are λ, μ, ν the theorem may also be given as

$$\int_S \left[\lambda \left(\frac{\partial w}{\partial y} - \frac{\partial v}{\partial z} \right) + \mu \left(\frac{\partial u}{\partial z} - \frac{\partial w}{\partial x} \right) + \nu \left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y} \right) \right] dS = \oint (u\,dx + v\,dy + w\,dz).$$

STOP. The opening, **diaphragm,** or **aperture** which limits the cross section of the beam of light which may pass through an optical system It may be the rim of a lens, or it may be an especially-introduced diaphragm. The location of the stop (aperture stop) frequently plays an important role in reducing **aberrations** in the system

STOPPING. The decrease in kinetic energy of an ionizing particle as a result of energy losses along its path through matter

STOPPING CAPACITOR. Another name for blocking capacitor (See **capacitor, blocking.**)

STOPPING CROSS SECTION. A synonym for atomic **stopping power.**

STOPPING POTENTIAL. See **potential, stopping.**

STOPPING POWER. A measure of the effect of a substance upon the kinetic energy of a charged particle passing through it. The linear stopping power S_l is the energy loss per unit distance, and is given by $S_l = -dE/dx$, where E is the kinetic energy of the particle

and x is the distance traversed in the medium. The mass stopping power S_m is the energy loss per unit surface density traversed, and is given by $S_m = S_l/\rho$, where ρ is the density of the substance. The atomic stopping power S_a of an element is the energy loss per atom, per unit area normal to the particle's motion, and is given by $S_a = S_l/n = S_mA/N$; where n is the number of atoms per unit volume, N is the Avogadro number, and A is the atomic weight. The molecular stopping power of a compound is similarly defined in terms of molecules; it is very nearly if not exactly equal to the sum of the atomic stopping powers of the constituent atoms. The relative stopping power is the ratio of the stopping power of a given substance to that of a standard substance, commonly aluminum, oxygen or air. The stopping equivalent for a given thickness of a substance is that thickness of a standard substance capable of producing the same energy loss. The air equivalent is the stopping equivalent in terms of air at 15°C and 1 atm as the standard substance. The term equivalent stopping power is not clearly defined, but sometimes is used synonymously with relative stopping power and sometimes with stopping equivalent.

STORAGE. In **computer** terminology, (1) any device into which information can be introduced and then extracted at a later time. The mechanism or medium in which the information is stored need not form an integral part of a computer. (2) The act of storing information.

STORAGE CAPACITY. The maximum number of distinguishable stable states in which a **storage** device can exist. It is customary to use the logarithm to the base two of that number as a numerical measure of the storage capacity. In this case, the unit of storage capacity is a binary digit.

STORM. A violent disturbance of the atmosphere, either by wind or other undesirable meteorological conditions, such as rain, thunder and lightning, dust or sand, ice or sleet, etc.

STRAGGLING. The random variation or fluctuation of a property associated with ions of a given kind in passing through matter. Range straggling is the variation in the range of particles that are all of the same initial energy. Angle straggling is the variation in the direction of motion of particles after passing through a certain thickness of matter, the paths of the particles initially being parallel. Statistical straggling is that variation in range, ionization or direction which is due to fluctuations in the distance between collisions in the stopping medium and in the energy loss and deflection angle per collision. Instrumental straggling is that additional straggling which is due to such instrumental effects as noise, gain instability, source thickness, and poor geometry.

STRAIN. The deformation produced in a solid as a result of **stress.** The components of strain may be written e_{xx}, e_{yy}, etc., where

$$e_{xx} = \frac{\partial u}{\partial x}, \quad e_{xy} = e_{yx} = \frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}, \quad \text{etc.};$$

u, v, w, are the components of the displacement of the particles, measured at the point x, y, z. The sum $e_{xx} + e_{yy} + e_{zz}$ is the **dilation,** and the components of type e_{xy} are called **shear** strains.

STRAIN, DILATATIONAL. A dilatation is a change in length or volume of a deformable body. A dilatational strain is the change in volume divided by the original volume or the change in length (as in a rod or wire) divided by the original length. The former is usually called a volume strain, the latter a linear strain. Both are known as dilatational strains because a change of size of the body is involved.

STRAIN, LINEAR. See **dilatational strain.**

STRAIN, NON-UNIFORM. A **strain** which, as in a non-homogeneous anisotropic body, varies from point to point under the same **stress.**

STRAIN, PERMANENT. See discussion of **permanent set.**

STRAIN, SHEAR. The **strain** resulting from the application of a **shear** stress, by which parallel planes in a body suffer relative displacement. The relative displacement divided by the perpendicular separation of the planes is the measure of the shear strain.

STRAIN-VIEWER. A viewer utilizing the passage of **polarized light** through glass or other isotropic transparent media in order to observe strained regions.

STRAIN, VOLUME. See discussion of **strain, dilatational.**

STRAP. In magnetrons, the link connecting alternate **resonator** segments. (See **magnetron, strapping.**)

STRATOCUMULUS. Layer consisting of large lumpy masses of **cloud.** It is billowed, often appears in rolls with occasional blue showing between rolls. The cloud casts considerable shadow with shades varying from very whitish in thin spots to very dark in thick spots. Types vary from almost true **cumulus** to almost true **stratus.**

STRATOSPHERE. That portion of the earth's **atmosphere** above the **tropopause.** This air is free of all weather phenomena, being practically without moisture, and having, in general, an isothermal structure.

STRATUS. Uniform layer of dull, grayish, low-level **cloud.** It is not the low-level equivalent of **altostratus**, rather it is more a cloudlike fog. Fragments of stratus torn by wind or remnants of clearing stratus are usually known as fractostratus.

STREAM FUNCTION. See **current function.**

STREAMLINE. A line which is always parallel to the local direction of flow, defined by

$$\frac{dx}{u} = \frac{dy}{v} = \frac{dz}{w}$$

where dx, dy, dz are the components along the three axes of the line element dl, and u, v, w are the components of the flow velocity. In steady flow, the streamlines are identical with the paths of fluid particles. In two-dimensional flow, the streamlines are lines of constant stream function.

If the streamlines follow closely the contours of a solid body placed in a moving fluid, the drag is usually low and the body is said to be of streamline form.

STREAMLINES IN THE ATMOSPHERE. Lines drawn everywhere tangent to wind vectors. They show the instantaneous flow-pattern of the air at a given time only, and do not indicate trajectories of **air parcels.**

STREAM TUBE. A stream tube is generated by the **streamlines** passing through every point on a closed contour. By definition of a streamline, there is no flow out of a stream tube except through its ends, and in steady flow the mass flow across any section is constant.

STREAMING. Unidirectional flow.

STREAMING, MOLECULAR, THEORY OF. Application of kinetic theory to the flow of gas through a tube at low pressures, such that the **mean free path** is large compared with the diameter of the tube. In this case, the streaming of the gas is due to the random motion of the molecules, and to the density gradient down the tube, so that the numbers of molecules traversing a given cross-section in opposite directions is different. For a tube of circular cross-section, the mass flowing per second is proportional to the pressure difference and the cube of the radius.

STREAMING POTENTIAL. A difference of **electrical potential** between a porous diaphragm, or other permeable solid, and a liquid which is passing through it.

STREAMING, SOUND. The production of unidirectional flow currents in a medium, arising from the presence of sound waves.

STRENGTH OF A SOUND SOURCE. See **sound source, strength of.**

STRESS. The force acting on a unit area in a solid, as in the theory of **elasticity.** In general, the stress has nine components, X_x, X_y, X_z, Y_x, etc., defined so that, e.g., X_y represents the force in the x direction acting on unit area of a plane whose normal is in the y direction. However, for equilibrium it is necessary that $Y_z = Z_y$, $Z_x = X_z$ and $X_y = Y_x$. The component of a stress which acts at right angles to a surface is known as the normal stress. If this stress is produced by a load whose **resultant** passes through the **center of gravity** of the area, it is called an axial or direct stress and is always uniformly distributed over the area. A normal resultant force which causes the fibers to increase in length is a tensile stress, while one which shortens the fibers is a compressive stress. The latter is often called a bearing stress. The component of any stress which lies in the plane of the area is a shearing stress.

Direct tensile or compressive stresses are known as primary stresses. The bending stress, resulting from deflection, is called a

secondary stress. The stresses developed in a column due to the lateral deflections are of a secondary nature. The rigidity of the riveted or welded joints of a truss which has deflected due to the axial **deformation** of its members causes bending stresses in the members which are classified as secondary stresses. The resistance offered by a body to a combination of direct and bending loads is frequently called a combined stress. A normal stress which occurs at a point in a plane on which the shearing stress is zero is known as a principal stress. If this normal stress is tensile it is often called a diagonal tension stress; if compressive it is known as a diagonal compression stress.

The internal resisting force which arises in a restrained body due to temperature changes is a thermal stress. The adhesive resistance which is developed in the concrete surrounding the steel reinforcing rods when a reinforced concrete member is subjected to load is known as bond stress. Safe unit resisting forces which are used in design are called working stresses. These are usually taken as a percentage of the ultimate stress or the elastic limit of the material.

STRESS, COMPRESSIVE. Force per unit area in a material medium directed in such a way as to produce a change in density in the region where the stress is applied. In the case of a fluid any change in the **equilibrium pressure** constitutes a compressive stress. In a fluid the compressive stress at any particular point is the same in every direction. Compressive stress is always associated with dilatational strain. (See **strain, dilatational.**)

STRESS, SHEARING. Force per unit area in a material medium directed tangentially to a set of parallel planes in such a way as to produce relative motion of the planes parallel to themselves, i.e., a shearing **strain.** A steady shearing stress cannot be applied to a perfect fluid, but is readily applicable to real fluids, where it is exemplified by **viscosity.**

STRESS-STRAIN CURVE. A stress-strain curve is a graphical representation of the relation between unit **stress** and unit **deformation** in a stressed body as a gradually increasing **load** is applied.

STRESS, TENSILE. Force per unit area directed perpendicular to one surface only in a material medium. It is associated with a linear strain (see **strain, linear**) in its direction.

STRESS TENSOR. The components of the stress tensor in a continuous material are the stresses exerted across surfaces normal to the directions of variation of a single coordinate. In Cartesian coordinates, the typical component, p_{ij}, is the component of the force per unit area in the Ox_j direction across a surface with normal parallel to Ox_i, exerted by the material at larger values of x_i on material of smaller values of x_i. (i and j may take the values 1, 2, 3 corresponding to the three axes.) The stress tensor is necessarily symmetric, i.e., $p_{ij} = p_{ji}$.

STRESS, TORSIONAL. The **shearing stress** which occurs at any point in a body as the result of an applied **torque** or **torsional load** is called a torsional stress. If the body is a circular shaft, the stress is found from the formula:

$$s_s = \frac{Tc}{J}$$

in which s_s = required **unit stress,** T = torque, c = radial distance from the center of the shaft to the point, J = **polar moment of inertia** of the cross-sectional area

This formula is based on the assumption that a plane section before twisting remains a plane after the torque is applied; also that the radii remain straight. The theory of **elasticity** shows that these assumptions are true for all sections except those adjacent to the applied torque and the supports.

The cross-section of a non-circular body becomes decidedly warped after twisting, so the stress must be obtained by formulae developed from the theory of elasticity, by experimental means or by approximate formulae which are given in textbooks on advanced strength of materials.

STRIATED DISCHARGE. The presence of alternate light and dark bands in the **positive column** of a gas **discharge,** generally due to a mixture of gases.

STRIATION (STRIA, PL. STRIAE). (1) A striped appearance of the positive column of a **Crookes tube.** (2) A defect of optical materials, such as optical glass, having the appearance of streaks through the material, and seriously affecting the material for use as lenses or windows.

STRIATION TECHNIQUE. A method for rendering sound waves visible by using their individual ability to refract light waves.

STRIKING POTENTIAL. See **potential, striking.**

STRING GALVANOMETER. See **galvanometer, string.**

STRIPPING. An effect observed in bombardment with deuterons or heavier nuclei, whereby only part of the incident particle merges with the target nucleus, and the remainder proceeds with most of its original momentum in practically its original direction. The effect is strongly marked in deuteron bombardment, and in this case typically leads to directional neutron and proton beams that emerge from the target (if the latter is sufficiently thin) predominantly in the forward direction. The angular divergence of the beams decreases with increasing energy of the incident deuterons. Subsidiary peaks are sometimes observed at rather small angles relative to the forward direction. When the (d,p) type of stripping occurs with deuterons having energies smaller than or comparable with the **Coulomb barrier** of the target nucleus, it is often called the **Oppenheimer-Phillips** process.

STROBE CIRCUIT. The name sometimes given to some form of time-selection **transducer.**

STROBOSCOPE. An instrument for viewing moving objects so they appear stationary. In its simplest form it may consist of a revolving disk with holes spaced around the edge, the moving object being observed through these holes. Since the object can be seen only when a hole is opposite the eye, a cyclic motion can be made to appear stationary if the speed of the disk is adjusted so a hole comes opposite the eye only when the moving object reaches the same point in each cycle; at other times the disk blocks out the view. As the object is thus always seen in the same position, the persistence of vision makes it appear to be still. The principal drawback to this type stroboscope is the blurring of rapidly moving objects since they can be seen for a short time while the disk hole is moving before the eye. Much more accurate stroboscopes utilize a flashing light to illuminate the moving machine. Again, if the light flashes once for each cycle of the motion the eye sees it only in one position, i.e., that at which the flash occurs. Even though the machine may have general illumination so the observer sees the usual blur of a rapidly moving machine, the flash of stroboscopic light causes it to appear stationary. The stroboscope is useful for observing the action of rotating parts, and obtaining their angular velocity.

STROBOTRON. A special, cold-cathode **gas tube** for supplying a short-duration, high-intensity **arc** for a **stroboscope.**

STRONG ELECTROLYTE. See **electrolyte, strong.**

STRONG ELECTROLYTES, ANOMALY OF. See **electrolytes, anomaly of strong.**

STRONG EQUALITY. Equality between two dynamical variables which implies that the **Poisson bracket** of the difference between them with any operator is zero

STRONTIUM. Metallic element Symbol Sr. Atomic number 38.

STROUD AND OATES BRIDGE. See **bridge, Stroud and Oates.**

STROUHAL FORMULA. The frequency f, in cycles/sec, of a stretched wire is related to the velocity of air flowing past at right angles to the wire by the equation

$$f = 0.185v/d,$$

where v = velocity of relative motion of wire and air in cm/sec, d = diameter of the wire in cm.

STRUCTURALLY-DUAL NETWORK. See **network, structurally dual.**

STRUCTURALLY SYMMETRICAL NETWORK. See **network, structurally symmetrical.**

STRUCTURE. The grouping of the various parts of an assembled entity, and the points at which, or the means by which, they are held together.

STRUCTURE AMPLITUDE OR STRUCTURE FACTOR. In the diffraction of **X-rays** by crystals, the amplitude of the beam which is reflected, according to the **Bragg law,** from the **atomic plane** (hkl), depends on a factor which represents the sum of the scattering by the individual atoms weighted by the appropriate **phase factors.** This structure factor

depends only on the **crystal structure,** and may be written

$$F(hkl) = \Sigma_n f_n \exp 2\pi i \left(\frac{hx_n}{a} + \frac{ky_n}{b} + \frac{lz_n}{c}\right)$$

where x_n, y_n, z_n are the coordinates of the nth atom in the unit cell, whose dimensions are a, b, c. f_n is the **atomic scattering factor** of the nth atom, and the summation is over all the atoms in the unit cell. In general, only the square modulus $|F(hkl)|^2$ can be measured experimentally, and the phase factors have to be guessed.

STRUCTURE, ATOMIC. The internal structure of the **atom,** comprising its nucleus and the electrons which surround it.

STRUCTURE, MOLECULAR. The internal structure of the **molecule,** comprising the various **atoms,** and the valence **bond** structure which holds them together.

STRUCTURE, NUCLEAR. The internal structure of the atomic **nucleus.**

STUB, DETUNING. A quarter-wave **balun** or matching stub, used to match a **coaxial line** to a sleeve-stub antenna (see **antenna, sleeve-stub**). The stub or **choke** prevents energy loss and pattern distortion by the prevention of current flow down the outside of the coaxial feed line. It thus performs a **detuning** function for the outside of the line, but a **tuning** function for the rest of the system

STUB-MATCHING, SINGLE AND DOUBLE. The use of single and double stubs to effect maximum power transfer from a transmission line to a load or other transmission medium.

STUB-TUNERS, SINGLE AND DOUBLE. Adjustable sections of short-circuited transmission lines added to a transmission line to "tune" or adjust it for maximum power transfer. The position of the stub as well as its length must be adjusted to secure perfect match with a single stub. With two stubs located a quarter of a wavelength apart, most matching problems can be solved without moving the stubs with respect to the load

STURM-LIOUVILLE EQUATION. A **differential equation** of the form

$$\frac{d}{dz}\left[p(z)\frac{dy}{dz}\right] + [g(z) + \lambda w(z)]y = 0$$

where λ is a parameter, the **eigenvalue,** chosen so that the solutions y, the **eigenfunctions,** satisfy given **boundary conditions.** The quantity $w(z)$ is a **weighting function** used so that the eigenvalues are **orthogonal**

$$\int w(z)y_n(z)y_m(z)dz = 0.$$

Nearly every eigenvalue problem in mathematical physics is of this form.

STURM THEOREM. A method for locating the real **roots** of a **polynomial equation.** Let $P(x) = 0$ be the equation with real coefficients and without multiple roots. Modify the usual process for finding the highest common factor of $P(x)$ and its first derivative $P_1(x)$ by exhibiting each remainder as the negative of a polynomial P_k, thus:

$$P = q_1P_1 - P_2,\quad P_1 = q_2P_2 - P_3,$$
$$P_2 = q_3P_3 - P_4,\ \cdots,$$
$$P_{n-2} = q_{n-1}P_{n-1} - P_n,$$

where P_n is a constant but not zero. If a and b are real numbers, with $a < b$, neither of which is a root of $P(x) = 0$, then the number of real roots of $P(x) = 0$ between a and b is equal to the excess of the number of variations of sign for

$$P(x),\ P_1(x),\ P_2(x),\ \cdots,\ P_{n-1}(x),\ P_n,$$

for $x = a$ over the number of variation of signs for $x = b$. Terms which vanish are to be dropped out before counting the variations of sign

SUBAQUEOUS SIGNALING. Discussed under **sonar.**

SUBATOMIC. Pertaining to processes or reactions in which atoms undergo **disintegration,** as in natural or artificial **radioactivity;** or to particles or radiations yielded by such reactions, such as **electrons, positrons, protons, neutrons, helium nuclei,** and nuclear fragments of larger size.

SUBCARRIER. A **carrier** which is applied as a **modulating wave** to modulate another carrier or an intermediate subcarrier.

SUBGROUP. Elements of a **group,** less in number than the **order** of the group, which satisfy the group postulates. Every group possesses at least two **subgroups:** the **unit element** and the group itself.

SUBGROUP, CONJUGATE. If H is a **subgroup** of the group G and X is an element of G, but not necessarily contained in H, then $X^{-1}HX$ is also a subgroup of G and a **conjugate subgroup** to H.

SUBGROUP, INVARIANT. If H and $H' = X^{-1}HX$ are **conjugate** then these two **subgroups** are **invariant** if $H = H'$. Also called normal subgroup or normal divisor.

SUBHARMONIC. A sinusoidal quantity having a frequency which is an integral submultiple of the fundamental frequency (see **frequency, fundamental**) of a periodic quantity to which it is related. For example, a wave, the frequency of which is half the fundamental frequency of another wave, is called the second subharmonic of that wave.

SUBLIMATE. The condensed vapor from the process of **sublimation,** analogous to the distillate from distillation.

SUBLIMATION. The transformation of a solid directly to the gaseous condition without passing through the liquid state. When the vapor pressure of a solid becomes greater than the atmospheric pressure the solid vaporizes completely at constant pressure. The temperature at the point where the vapor pressure of a solid equals the atmospheric pressure is its sublimation temperature.

SUBLIMATION CURVE. The graphical representation of the variation with temperature of the **vapor pressure** of a solid

SUBLIME. To pass from the solid directly to the gaseous state without melting.

SUBMICRON. In Zsigmondy's nomenclature, submicrons are particles between 5×10^{-9} and 10^{-7} meters in diameter (50–1000 Ångström units).

SUBSIDENCE. Subsiding air is sinking air and is associated with lateral divergence. Subsidence in the atmosphere is a stabilizing influence; it also decreases relative **humidity** within the sinking air as it warms the air. Atmospheric pressure usually rises under the influence of subsidence, which is normally associated with **anticyclones.** Clear or partially-clouded skies are the usual weather in a region of subsidence.

SUBSONIC FREQUENCY. See **frequency, infrasonic.**

SUBSTANCE. A term used to designate a pure chemical compound or a definite mixture of such compounds. The term substance should not be used as an equivalent to the term "body" which refers to a definite mass of material, i.e., two different masses of the same substance would constitute two "bodies" but not two substances.

SUBSTITUTIONAL ALLOY. A class of **metallic alloy** in which atoms of one element have been replaced by atoms of another, without changing the basic crystal structure.

SUBSTITUTION METHOD. See **physical measurements.**

SUBTRACT CIRCUIT. See **comparator.**

SUBTRACTIVE COLOR PROCESS. A method of photographic color synthesis using two or more superimposed colorants which selectively absorb their complementary colors from white light.

SUDDEN IONOSPHERIC DISTURBANCE. See **magnetic storm.**

SUHL EFFECT. **Holes** injected into an n-type semiconducting filament are deflected by a strong transverse magnetic field to the surface, where they may recombine rapidly with electrons showing a much reduced **lifetime.** or be withdrawn by a probe as if the conductance had increased.

SULFUR. Nonmetallic element Symbol S. Atomic number 16.

SUMMATION BAND. See **band, summation.**

SUMMATION CONVENTION. An abbreviated notation, used frequently in **algebra,** but especially in **tensor analysis.** Instead of writing

$$\sum_{k=1}^{n} \frac{\partial \bar{x}^i}{\partial x^k} A^k, \quad i = 1, 2, \cdots, n$$

omit the summation sign and remember that summation is to be carried out for the repeated index k. Such an index is often called a dummy or umbral **index.** The letter used for a dummy index can be changed without changing the meaning of the expression

$$\frac{\partial \bar{x}^m}{\partial x^j} A^j = \frac{\partial \bar{x}^m}{\partial x^n} A^n, \text{ etc.}$$

For the meaning of the upper index, see **tensor, contravariant.**

The summation convention is used particularly in **relativity theory,** where the summation is over the values 1, 2, 3, 4 (three position coordinates and one time coordinate). In this case an expression of the form $A_{\mu\nu}B_{\nu\sigma}C_{\sigma\tau} \cdots$, denotes the value obtained by summing over values of the dummy indices, $\nu, \sigma \cdots$.

SUMPTNER PRINCIPLE. When a source of light is placed at any point inside a sphere with perfectly diffusing walls, every part of the interior is equally illuminated.

SUNLIGHT RECORDER. A device used in **meteorology** and agronomy, which records the time integral of the sun's visible radiation. The output of a **phototube** is integrated in a capacitor **integrator,** the output of which is, in turn, integrated by a **thyratron**-operated mechanical counter.

SUP. A symbol used to represent the **suppressor grid** of a **vacuum tube.**

SUPERCONDUCTING TRANSITION. The change from the normal to the superconducting state is a reversible phase transition of the second kind, taking place at a temperature which depends on the magnetic field as well as on the material. The entropy of the normal state is always greater than that of the superconducting state by an amount

$$-\frac{H_c}{2\pi}\frac{dH_c}{dT},$$

where H_c is the **critical field** at temperature T.

SUPERCONDUCTIVE STATE, THERMODYNAMIC FUNCTIONS OF. Owing to the existence of the **Meissner effect,** a superconductor can be described in a thermodynamic diagram of state with the temperature as the independent, and the magnetic field as the dependent, variable.

SUPERCONDUCTIVITY. At very low temperatures, certain metals, alloys, and compounds go through a **superconducting transition** into a state in which the electrical resistance has a value of zero. The **critical temperature (2)** of the superconductor and the **critical** magnetic **field** curve characterize the material. Persistent electric currents may be induced in a superconducting ring, and show no signs of decay. However, the **Meissner effect** cannot be explained by zero resistance alone, and the **London equations** have been invoked to give a macroscopic description of the superconducting state. For many purposes the two-fluid model is convenient e g, in analyzing thermodynamic and thermoelectric effects Other properties of superconductors are associated with the ideas of the **intermediate state** and **penetration depth.**

Apart from variations in the parameters, the phenomena of superconductivity are essentially similar from substance to substance No complete fundamental theory exists, although progress has recently been made by Fröhlich and Bardeen. (See **Fröhlich and Bardeen theory.**)

SUPERCONDUCTIVITY, TWO FLUID MODEL. A phenomenological theory of **superconductivity,** according to which the **conduction electrons** belong to two interpenetrating assemblies having radically different properties. The "normal" electrons show electrical resistivity, etc., while the superconducting electrons have zero entropy and resistivity. The proportion of normal electrons that have not been "condensed" into the superconducting state at temperature T is $(T/T_c)^4$ where T_c is the **superconducting transition** temperature in zero field.

SUPERCONDUCTOR. A substance exhibiting **superconductivity.**

SUPERCONDUCTOR, HARD, OR NONIDEAL. Certain superconducting compounds and alloys show high transition temperatures, high **critical fields,** incomplete **Meissner effect,** breakdown of the **Silsbee rule,** etc. The effect may be reproduced by application of severe inhomogeneous strains.

SUPERCONDUCTOR, LONDON ELECTRODYNAMICAL THEORY OF. A phenomenological treatment of superconductivity has been developed by F. and H. London, in which the Maxwell acceleration equation is replaced by a differential equation connecting the current with the magnetic, instead of the electric, field.

SUPERCONTROL TUBE. See **variable mu tube.**

SUPERCOOLING. The cooling of a liquid below its freezing point without the separation

of the solid phase. This is a condition of **metastable equilibrium,** as is shown by solidification of the supercooled liquid upon the addition of the solid phase, or the application of certain stresses, or simply upon prolonged standing.

SUPERELEVATION (I.E., BANKING OF A TRACK OR ROAD). The vertical distance the outer track of a railway is raised above the inner track on a curve in order to compensate for the effect of the centrifugal force associated with motion around the curve.

SUPEREXCHANGE. A mechanism invoked to explain strong antiferromagnetic coupling such as that, for example, between two Mn^{++} ions separated by an O^{--} ion in MnO. A form of **configuration** interaction is involved —one of the excess electrons on the oxygen ion goes on to one of the Mn^{++} ions, where it couples with its spin. The other electron on the oxygen ion must be of opposite spin by the **Pauli exclusion principle,** and couples by exchange with the spin of the remaining Mn^{++} ion The overall effect is thus a coupling between the spins of the Mn^{++} ions, even though these are much too far apart to have a direct **exchange** interaction.

SUPERHET. Colloquialism for superheterodyne. (See **receiver.**)

SUPERHETERODYNE. See **receiver.**

SUPERHETERODYNE, DOUBLE. A receiver which employs two **heterodyne mixers,** local **oscillators,** and **i-f amplifiers.** The i-f amplifiers are of different frequency, thus permitting higher **gain** without instability.

SUPERIMPOSITION APPROXIMATION. The assumption that in any system comprising molecules in fixed positions, the force on any molecule is the sum of the forces which would be exerted on the given molecule by all other molecules in turn acting as if all the remaining molecules were not present.

SUPERLATTICE. A type of arrangement of atoms in a multi-component solid system, in which the atoms of an element occupy certain regular positions in the **atomic lattice** of another element even though no compound between the two elements of that composition can be separated or otherwise identified.

SUPERMALLOY. Trade name of a **permalloy**-type of magnetic alloy with a maximum **permeability** in excess of one million.

SUPERPOSITION, PRINCIPLE OF. If a physical system is acted on by a number of independent influences, the resultant influence is the sum (vector or algebraic as circumstances dictate) of the individual influences. The principle takes on many specific forms depending on the nature of the system and the influence in question. For example, when two forces act simultaneously on a particle the resultant force is the vector sum of the two. Another example is provided by the small oscillations of a system about a state of equilibrium. Thus the total displacement of a vibrating string is the algebraic sum of all its various harmonic modes of **oscillation** which add without interfering with each other. The principle is validated in this case by the fact that the wave equation governing the oscillations is linear. Superposition does not apply to non-linear systems.

The principle can also be applied to **quantum mechanics.** Here it is exemplified by the postulate that any **state function** of a given quantum mechanical system corresponding to a given observable (e.g., the energy) can be expressed as a linear expansion of the **eigenstates** of the system for the same observable.

SUPERPOSITION PRINCIPLE OF NERNST. The **potential difference** between **junctions** in similar pairs of solutions which have the same ratio of concentrations are the same even if the absolute concentrations are different, e.g., the same potential difference exists between normal solutions of HCl and KCl as exists between tenth-normal solutions of HCl and KCl.

SUPER-REFRACTION. The transmission of microwave frequencies far beyond line of sight due to an **atmospheric duct.**

SUPER-REGENERATIVE RECEIVER. In the ordinary regenerative **receiver** the sensitivity goes up as the **feedback** is increased, but if the feedback is increased to produce the maximum amplification (just before oscillations start) the circuit is unstable and breaks into oscillation. The super-regenerative circuit utilizes this high gain point without the instability, by introducing a voltage of low radio frequency in the plate supply lead.

Since this voltage subtracts from the plate supply voltage every half-cycle, it will lower the net plate voltage to the point where any started oscillations die out. The circuit is adjusted so oscillations actually start to build up, giving very high gain, but are killed off at the low radio frequency (quench frequency) rate and so do not reach an objectionable amplitude. The quenching frequency may be generated by a separate oscillator **tube,** or may be generated by the regular detector tube in a so-called self-quenching circuit. The gain of these detectors is enormous, but they are subject to several limitations such as: poor quality, radiation and subsequent interference with other receivers, strong interchannel hiss, poor selectivity, etc. They are, nevertheless, quite widely used for reception in the **very high frequency** region.

SUPERSATURATE. To carry a process beyond **saturation,** as to supersaturate a solution.

SUPERSATURATED AIR. Air devoid of salt, dust, and ions can be supersaturated with respect to a free water surface. Inasmuch as the atmosphere contains numerous salt particles, dust, and ions, as well as microscopic plants and animals, supersaturation is seldom if ever a reality, because these materials, particularly salt particles and ions, serve as nuclei for condensation. Actually many clouds form at less than saturation with respect to open water surfaces.

SUPERSATURATION. The condition of containing an excess of some material over the amount required for **saturation.**

SUPERSONIC SOUNDING. See **sonar.**

SUPERSONICS. The general subject covering phenomena associated with speed higher than the speed of sound (as in case of aircraft and projectiles traveling faster than sound). At one time, this term was used in acoustics to denote the general subject of high frequency sound (**ultrasonics**). Such usage is now deprecated.

SUPER-SYNC. The combined horizontal and vertical synchronizing signals of standard **television transmission.**

SUPPLEMENTARY CONDITION. Any condition imposed on the state vector Φ in a quantized field theory (see **field theory, quantized**) in order that this vector should correspond to an actual state; e.g., in **quantum electrodynamics,** the **Lorentz condition**

$$\frac{\partial A_\mu}{\partial x_\mu}\Phi = 0.$$

SUPPRESSED CARRIER. See **modulation.**

SUPPRESSOR. An element or device used in electric or electronic components or circuits to prevent or reduce undesired actions or currents. Examples are series resistors in certain high-voltage circuits to prevent sparking; additional grids in vacuum tubes to prevent secondary emission from the plate. (See **grid, suppressor.**)

SUPPRESSOR GRID. See **grid, suppressor.**

SURFACE. The **locus** of points satisfying an equation in three variables $f(x,y,z) = 0$. (See also **area.**)

SURFACE-ACTIVE COMPOUNDS. Those substances that lower the surface tension of a liquid when exposed to a gas, e.g., water in air, or reduce the interfacial tension between two immiscible liquids, e.g., kerosene and water.

SURFACE BALANCE (LANGMUIR). An apparatus for the measurement of surface pressure and surface area of monomolecular films on water. The surface pressure is measured by arranging a floating barrier on the surface of the water with a device for measuring the force acting on the barrier.

SURFACE DECAY CONSTANT. The reciprocal of the **lifetime** of a **carrier** in a **semiconductor** when this is governed by surface recombination.

SURFACE DENSITY. The quantity per unit area of anything distributed over a surface. Examples are electric charge per unit area and mass per unit area. It is in the latter sense that the term is used in nuclear physics, this being a common way of indicating an absorber thickness, source thickness, target thickness, support thickness for thin radioactive sources, etc.

SURFACE DUCT. An **atmospheric duct** for which the lower boundary is the surface of the earth.

SURFACE ENERGY. See **energy, surface.**

SURFACE ENERGY, FREE. The work necessary to increase the area of the surface of a liquid by unit area. Usually expressed in ergs per square centimeter.

SURFACE ENERGY, INTERFACIAL. The work necessary to increase the surface of separation between two liquids by unit area.

SURFACE FILM, CONDENSED. A **film** of an insoluble substance, on the surface of a liquid, and consisting of a **monolayer** of closely packed molecules, at or near the point at which further compression of the film causes the formation of crystals of solid or lenses of liquid in equilibrium with the monolayer.

SURFACE OF REVOLUTION. The result of revolving a plane curve about a line lying in its plane Special cases of each of the **quadric surfaces** may be produced in this way.

SURFACE ORIENTATION. The occupation of such positions by certain molecules in the surface of a liquid that one part of the molecule is turned toward the liquid; as, e.g., on the air-liquid interface of an aqueous system, molecules containing polar and nonpolar groups arrange themselves with the polar groups directed toward the water.

SURFACE RECOMBINATION VELOCITY. Experiments show that electrons and **holes** in **semiconductors** recombine much more readily on the surface of the material than they do in the interior. The process is analyzed in terms of a parameter s, i.e., the velocity with which the carriers would have to drift to the surface, and there be removed, to match the observed recombination rate.

SURFACE, RULED. A **surface** that is generated by the motion of a straight line called the **generatrix.** Any **quadric surface** can be produced in this way but the generatrix is real only for the cone, cylinder, hyperboloid of one sheet, and hyperbolic paraboloid. In the other possible cases, the generatrix is imaginary.

SURFACE STATES. According to a theory of Bardeen, there is a tendency for electrons in a **semiconductor** to be tightly bound into states on the surface of the sample. This is the basis of the **Bardeen-Brattain theory of hole injection.**

SURFACE TENSION. The molecules close to the surface of a liquid, unlike those in the interior, experience forces of attraction from their neighbors directed normally to the surface. The effect of this force is to make the liquid behave as if it were contained in a stretched elastic skin. The tension in this skin is the surface tension

SURFACE TENSION, COEFFICIENT OF. The coefficient of **surface tension** is the force per unit length that appears to act across lines drawn in the surface of the fluid It measures the mechanical effects of the internal energy of the surface layer.

SURFACE TENSION, METHODS OF MEASUREMENT. (1) Drop weight method. A drop suspended below a tube of radius r and slowly increasing in size detaches itself when its weight is

$$mg = 2\pi r\gamma F\left(\frac{\rho g r^2}{T}\right)$$

(γ is surface tension, ρ density of the liquid). The function F is of order unity

(2) Tensiometer method This method measures the force necessary to detach a ring of known radius from the liquid surface, often by a **torsion balance.** The surface tension is the force divided by twice the perimeter of the ring.

(3) Capillary rise method The rise of a liquid in a **capillary tube** is given by the **Jurin law,** and from it the surface tension may be calculated.

(4) Jaeger method (maximum bubble pressure). The pressure necessary to force air from a capillary tube of radius r immersed vertically a distance h into the liquid of density ρ is

$$p = p_0 + \rho g h + 2\gamma/r$$

where p_0 is the surface pressure.

(5) Sessile drop method. The shape of a **drop** resting on a surface that it does not wet depends on surface tension. Measurements of drop depth and weight are sufficient to determine the surface tension.

(6) Pendant drop method. A method similar to (5), but applicable to wetting fluids.

SURFACE TENSION, NUCLEAR. See **nucleus, liquid drop model of.**

SURFACE TENSION, UNITS OF. The dimensions of **surface tension** correspond to force per unit length. In the metric system the unit is dyne cm^{-1} and in the English system, lbf ft^{-1}.

SURFACE WAVES. (1) Waves of distortion on the free surface separating two fluid phases, usually a liquid and a gas or vapor of low density. The waves are classed as gravitational waves or ripples, depending on whether gravity or surface tension is the controlling force in their motion. (2) An electromagnetic wave component traveling parallel to the earth's surface. Also called the ground wave.

SURGE. (1) An oscillation of relatively great magnitude set up by an electric discharge in a line or system. (2) A general change in barometric pressure apparently superposed upon cyclonic and normal diurnal changes.

SURGE ELECTRODE CURRENT. An older term for **fault electrode current.**

SURVEY INSTRUMENT. A portable instrument, used for detecting and measuring radiation under varied physical conditions. The term covers a wide range of devices utilizing most of the detection methods defined elsewhere.

SUSCEPTANCE. The imaginary part of **admittance.** Note that if $Z = R + jX$,

$$A = \frac{1}{R + jX} = \frac{R - jX}{R^2 + X^2}$$

and the susceptance is

$$S = \frac{-X}{R^2 + X^2}.$$

SUSCEPTIBILITY, ELECTRIC. See **polarization (due to induced dipoles), dielectric constant, electric induction.**

SUSCEPTIBILITY, MAGNETIC. See **magnetic susceptibility.**

SUSPENDED TRANSFORMATION. The cessation of action before true **equilibrium** has been reached, or the failure of a system to readjust itself immediately when conditions are changed. **Metastable equilibrium, supercooling,** etc., are examples.

SUSPENSION. A system of particles dispersed in a liquid, which do not separate because of their small size, the motion imparted to them by collision with water molecules, etc. Such a system is also called a suspensoid, or a colloidal suspension.

SUTHERLAND EQUATION. A relationship between the mean free path of a molecule and the molecular diameter. This relationship is expressed in the following equation:

$$d \propto \frac{1}{nl\sqrt{1 + C/T}}$$

in which d is the molecular diameter, n is the number of molecules per unit volume, l is the mean free path, T is the absolute temperature, and C is the Sutherland constant.

SVEDBERG EQUATION. A relationship between the amplitude of a particle which exhibits Brownian movement and its period of vibration. The generalized form of this relationship is: $a \propto t$, in which a is the amplitude of vibration, and t is the period.

SWEEP. A steady change in the value of a quantity in order to delineate a characteristic. Examples of swept quantities are (1) the displacement of a **scanning spot** on the screen of a cathode-ray tube, and (2) the frequency of a **wave.**

SWEEP FREQUENCY. The rate at which a complete sweeping cycle occurs. (See **sweep.**)

SWEEP VOLTAGE. See **voltage, sweep.**

SWELLING. The phenomenon observed when certain solid substances absorb liquids with which they are brought in contact with the result that they increase in volume. Examples are dry gelatine or agar placed in water. A similar behavior is found with many natural and synthetic **polymers** in organic solvents.

SWINGING CHOKE. A variable inductance **choke** often used as the input choke for a smoothing **filter** of a **power supply.** The requirements for the input choke vary with the load on the filter so one value of inductance is needed for no load (other than the bleeder across the filter output) and a much lower value is needed when load is applied. By proper adjustment of the air gap in the **core**

of an iron-cored choke this variation in inductance can be made automatic as the current through it varies with the load demand.

SWITCH DETECTOR. See **detector, switch.**

SWITCHING. The connection of two points of a **network** at controllable instants of time. An alternative term is **clamping.**

SX-10. Term used by the General Electric Company to denote a grain-oriented, silicon-iron alloy.

SYLLABLE ARTICULATION. See **articulation, syllable.**

SYMMETRIC. Arranged in accordance with a certain similarity with reference to a certain geometrical entity or position, which may be a point (center or point of symmetry), a line (axis of symmetry), or a plane (plane of symmetry), etc. A symmetric function is transformed into itself when its variables are interchanged in pairs (See **antisymmetric** and **matrix, symmetric; tensor, symmetric.**)

SYMMETRIC TOP MOLECULE. A non-linear molecule having only one axis of 3-fold or higher symmetry, where this axis is the axis of highest symmetry.

SYMMETRICAL NETWORK. See **network, structurally symmetrical.**

SYMMETRICAL TRANSDUCER. See **transducer, symmetrical.**

SYMMETRY, AXIS OF. A line drawn within a body or within a set of points in such a location and direction that a rotation of the body through an angle $(2\pi/n)$ radians about the line as an axis, n being an integer, greater than unity, results in a configuration indistinguishable from the original configuration. A body or set having such an axis is said to have n-fold symmetry, and the line is said to be an n-fold axis. Thus a line through the center of a cube and parallel to a face is a four-fold axis of symmetry, while a body diagonal of the cube is a two-fold axis.

SYMMETRY AXIS OF SECOND KIND OR ROTATION-REFLECTION AXIS. A **symmetry element** by which the crystal is brought into self-coincidence by a combined rotation and reflection in a plane perpendicular to the axis of rotation. In Schoenflies notation, S_n for an n-fold axis. (See **symmetry classes.**)

SYMMETRY, CENTER OF. A **symmetry element** such that any line through it will intersect the crystal at equal distances on either side. Schoenflies symbol, subscript i. (See **symmetry classes.**)

SYMMETRY CLASSES. Every crystal belongs to one of the 32 different classes of symmetry, or **point groups.** The standard notation for describing these classes is that of Schoenflies, who assigned symbols to the various possible **symmetry elements** according to the following rules:

Symbol	*Symmetry Element Possessed by Group*
C_n	n-fold axis
D_n	n-fold axis, and n two-fold axes perpendicular to it
S_n	n-fold axis of rotary-reflection
V	three mutually perpendicular two-fold axes
T (tetrahedral)	four three-fold axes towards vertices of regular tetrahedron
O	three mutually perpendicular four-fold axes (cubic group)
subscript v	(vertical) reflection plane containing symmetry axis
subscript h	(horizontal) reflection plane perpendicular to symmetry axis
subscript d	(dihedral) reflection plane bisecting angle between two two-fold axes
subscript i	inversion
subscript s	reflection plane

Another system of notation is that of the **Hermann-Manguin symbols.**

SYMMETRY, DYAD. A two-fold **symmetry axis.**

SYMMETRY ELEMENT. An operation which brings a crystal into a position that is indistinguishable from its original position. The symmetry elements are: rotation axes, reflection planes, inversion centers and rotation-reflection axes.

SYMMETRY, HEXAD. A six-fold **symmetry axis.**

SYMMETRY OPERATION. See **symmetry element.**

SYMMETRY, PLANE OF. A plane passed through a body or through a set of points in such a location and direction that the reflec-

tion of all points in the plane results in a configuration indistinguishable from the original configuration. Thus, a cube has many planes of symmetry through its center, including those parallel to the faces and those passing through face diagonals.

SYMMETRY, TETRAD. A four-fold **symmetry axis.**

SYMMETRY, TRIAD. A three-fold **symmetry axis.**

SYNC COMPRESSION. The reduction in **gain** applied to the **sync signal** over any part of its amplitude range with respect to the gain at a specified reference level. The gain referred to in the definition is for a signal amplitude small in comparison with the total **peak-to-peak composite picture signal** involved. A quantitative evaluation of this effect can be obtained by a measurement of differential gain Frequently the gain at the level of the peaks of sync pulses is reduced with respect to the gain at the levels near the base of the sync pulses Under some conditions, the gain over the entire sync signal region of the composite picture signal may be reduced with respect to the gain in the region of the picture signal.

SYNC LEVEL. The level of the peaks of the **sync signal.**

SYNC SIGNAL (SYNCHRONIZING SIGNAL). The signal employed for the synchronizing of **scanning.** In television, this signal is composed of pulses at rates related to the line and field frequencies. The waveform specified by the U.S. Monochrome Standards is shown under **television, sync signal.** The signal usually originates in a central sync generator, and is added to the combination of **picture signal** and **blanking signal,** comprising the output signal from the pickup equipment, to form the **composite picture signal.** In a television receiver, this signal is normally separated from the picture signal, and is used to synchronize the deflection generators.

SYNCHRO. An electrical system for remote control or indication. The typical system includes a rotating device which is supplied with single phase or polyphase power and has an output depending in phase, in amplitude, or in both on the position of the rotor. This output is amplified and fed to a second rotating device which follows the motion of the first.

SYNCHROCYCLOTRON. A **cyclotron** in which the radio frequency of the electric field is frequency-modulated to permit the acceleration of particles to **relativistic energies.**

SYNCRODYNE. A **homodyne detector** or **demodulator.**

SYNCHRONIZATION, LONG-TIME. A synchronization process for pulse systems, in which the timing operations are controlled by a sinusoidal component obtained by filtering the received pulse train with a **filter** having a very narrow **pass-band.**

SYNCHRONIZATION, START-STOP. Synchronization of a **pulse system** on a zero-delay basis.

SYNCHRONIZING (IN TELEVISION). Maintaining two or more **scanning** processes in phase.

SYNCHRONIZING COMPRESSION. See **sync compression.**

SYNCHRONIZING LEVEL. See **sync level.**

SYNCHRONIZING, POWER CIRCUITS. See **parallel operation.**

SYNCHRONIZING PULSES. See **sync pulses.**

SYNCHRONIZING, RADIO CIRCUITS. There are various types of synchronizing requirements in the field of radio and television engineering. In certain applications two or more **oscillators** need to be synchronized, i.e., tied together so their frequencies remain the same. This may be accomplished by injecting into each circuit a synchronizing signal from some common source (which may be one of the oscillators being synchronized). It is characteristic of many oscillator circuits that they will lock in frequency with an injected signal if its frequency is near the natural frequency of the oscillator or is a **harmonic** of the natural frequency. In **television** it is essential that the reproducing circuits of the receiver be synchronized with the transmitter camera device so the reconstructed scene will have its components in the proper places. This is accomplished by transmitting synchronizing pulses from the **transmitter.** In

many electronic devices the synchronization of various components of the system plays an extremely important part, but the basic method is that used for two oscillators.

SYNCHRONIZING SEPARATOR. That portion of a television receiver which operates the synchronizing signals (see **sync signal**) from the video signal.

SYNCHRONIZING SIGNAL. See **sync signal.**

SYNCHRONOMETER. An auxiliary device for frequency standards, which effectively counts the number of cycles executed by the standard in a given time-interval. It thus functions as an extremely accurate clock driven by the frequency standard.

SYNCHRONOUS CONDENSER. A synchronous **motor** operated over-excited and without load. Such a motor operates with a leading **power factor.**

SYNCHRONOUS CONVERTER. See **converter.**

SYNCHRONOUS DEMODULATOR. See **demodulator, homodyne.**

SYNCHRONOUS DETECTOR. See **detector, synchronous.**

SYNCHRONOUS GATE. A time gate wherein the output intervals are synchronized with an incoming signal.

SYNCHRONOUS IMPEDANCE. See **impedance, synchronous.**

SYNCHROTRON, ELECTRON. A device for accelerating electrons in a circular orbit in an increasing magnetic field by means of an alternating electric field applied in synchronism with the **orbital motion.**

SYNCHROTRON, PROTON. A device for accelerating protons (or deuterons or α-particles) in a circular orbit in an increasing magnetic field by means of an alternating electric field applied in synchronism with the orbital motion.

SYNERESIS. The contraction of a **gel** with accompanying pressing out of the interstitial solution or serum. Observed in the clotting of blood, with silicic acid gels, etc.

SYNOPTIC REPORTS AND CHARTS. In meteorology observed weather conditions are placed in brief coded form as a synopsis of the conditions. Such briefs of conditions are known as synoptic reports. Likewise, a map upon which an analysis of the data appears is known as a synoptic chart. Synoptic charts may show conditions at sea level, any other level, or in cross section.

SYNTHETIC DIVISION. An abbreviated process, using detached coefficients, for finding the **quotient** of a **polynomial** in one variable x by a divisor of the form $x - r$, where r is a constant. The procedure may be illustrated by the polynomial $a_0x^4 + a_1x^3 + a_2x^2 + a_3x + a_4$. The results can be obtained in the following form which is self-explanatory:

$$\begin{array}{lll} a_0 & a_1 & a_2 \\ & a_0r & A_1r \\ \hline a_0, & A_1 = a_0r + a_1, & A_2 = A_1r + a_2, \end{array}$$

$$\begin{array}{lll} a_3 & a_4 & r \\ A_2r & A_3r & \\ \hline A_3 = A_2r + a_3, & R = A_3r + a_4 & \end{array}$$

The quotient is $a_0x^3 + A_1x^2 + A_2x + A_3$ and the remainder is R. A similar process applies to a polynomial of any other degree. In the general case, if the coefficient of any power of x is missing, a zero should be supplied in the appropriate place in the first line of the scheme. If the remainder in the synthetic division is zero, then the divisor is a **factor** of the given polynomial.

SYSTEM. (1) A specified region, or portion of matter, containing a definite amount of a substance or substances, arranged in one or more phases. (2) A plan of arrangement of terms or entities, especially those composing a larger aggregate.

SYSTEM(S), BINARY, TERTIARY. . . . Systems composed of, respectively, two, three . . . **components**

SYSTEM, CONDENSED. A system from which the gaseous phase is absent or, more commonly, is disregarded because of its very slight effect upon the processes under consideration.

SYSTEM DEVIATION, MAXIMUM (FM SYSTEMS). The greatest **frequency deviation** specified in the operation of the system. In the case of FM broadcast systems in the

range from 88 to 108 megacycles per second, the maximum system deviation is 75 kilocycles per second.

SYSTEM, HETEROGENEOUS. A system having more than one **phase.**

SYSTEM, HOMOGENEOUS. A system having only one **phase.**

SYSTEM(S), NONVARIANT, MONOVARIANT, DIVARIANT. . . . Systems having, respectively, zero, one, two . . . **degrees of freedom.**

SYSTEM, STABLE. A system that can undergo considerable variation in external conditions, such as temperature, pressure, etc., without fundamental change.

T

T. (1) Temperature, absolute (T), temperature, Kelvin (T), temperature of freezing point of water (absolute, T_0) (ordinary t_0), ordinary temperature (t), critical temperature (t_c or T_c). (2) Time (t). (3) Reverberation time (T). (4) Transport number (T). (5) Radioactive half-life (T or $t_{1/2}$). (6) Oscillation period, or period of a periodic motion (T).

T SECTION. A network connection which has two elements in series in one line and a third element in shunt from the junction of the two series elements to the opposite line, thereby giving a circuit diagram which looks like a T.

TACAN. A word coined from the expression "tactical air navigation"; a system whereby the distance and bearing of an airplane from a fixed point is indicated on dials, or other devices within the airplane. Ultra-high-frequency signals pass between plane and ground station, the operator in the plane tuning to the station frequency. Because of the "straight-line" direction of these high-frequency waves, the effective range is essentially limited to the line of sight, and many ground stations are required in a complete system.

TACHOMETER. An instrument used to measure angular velocity, as of a shaft, either by registering the number of rotations during the period of contact, or by indicating directly the number of rotations per minute.

TACITRON. A **thyratron** capable of current interruption by grid action, which also generates much less noise than a conventional thyratron Its anode current can be turned on or off in about a microsecond without the necessity of anode voltage removal, due to a special grid design which limits ion generation to the grid-anode region.

TAILING. See **hangover.**

TAKING CHARACTERISTIC. See **camera spectral characteristic.**

TALBOT. The M.K.S. unit of luminous energy (see **energy, luminous**). One talbot is equal to 10^7 **lumergs.** One **joule** of radiant energy having a luminous energy efficiency of x lumens per watt is x talbots of luminous energy. One **lumen** is a luminous flux of one talbot per second.

TALBOT BANDS. If a glass plate of the proper thickness is inserted, from the side of the blue end of the spectrum, into a **spectroscope** so as to cover one-half of the **aperture,** a series of bands appear in the spectrum. (See Ditchburn, *Light*, for detailed explanation)

TALBOT LAW. The apparent **brightness** of an object viewed through a slotted-disk, rotating above a critical frequency, is proportional to the ratio of the **angular aperture** of the open to the opaque sectors.

TAMM-DANCOFF METHOD. Technique for approximating to the **wave-function** of a system of interacting particles, especially nucleons and mesons, by describing it as a superposition of a certain number of possible states. This number is decided upon *a priori* and determines the order of the approximation. No explicit assumption is made about the smallness of the interaction and indeed in contrast to the usual **perturbation theory** the theory of the motion is developed non-adiabatically, i.e , the equation of motion of the interacting particles is developed at the same time as the term describing their interaction.

TAMM LEVELS. See **surface states.**

TANDEM (CASCADE). Two-terminal pair **networks** are in tandem when the output terminals of one network are directly connected to the input terminals of the other network.

TANGENT. Take a point P on a curve, a neighboring point P', also on the curve, and draw the **secant** line PP'. As P' approaches P, the secant approaches a limiting position which is the **tangent** to the curve at P. The

slope of the tangent at P is frequently called the slope of the curve at that point.

If the curve is described by $y = f(x)$ and the coordinates of the point of tangency are $P(x_1,y_1)$, then the slope of the tangent is the derivative $f'(x_1)$. The equation of the tangent is

$$y - y_1 = f'(x_1)(x - x_1).$$

All tangents to a surface at a given point lie in a tangent plane to the surface. If the surface is given by $z = f(x,y)$, the equation of the tangent plane at the point (x_1,y_1,z_1) is

$$(x - x_1)\frac{\partial f}{\partial x} + (y - y_1)\frac{\partial f}{\partial y} = z - z_1,$$

where the **partial derivatives** are to be evaluated at the given point.

TANGENT GALVANOMETER. See **galvanometer, tangent.**

TANGENTIAL FOCUS. See **astigmatic focus.**

TANK. See **pool tube.**

TANK CIRCUIT. A circuit capable of storing electrical energy over a band of frequencies continuously distributed about a single frequency at which the circuit is said to be resonant, or tuned. The **selectivity** of the circuit is proportional to the ratio of energy stored in the circuit to the energy dissipated. This ratio is often called the **Q** of the circuit.

TANK CIRCUIT, *K* OF THE. The ratio of the **tank circuit** volt-amperes to watts dissipated, including the load, is sometimes called K. This ratio is more generally known as **Q.**

TANTALUM. Metallic element. Symbol Ta Atomic number 73.

TANTALUM DETECTOR. A **rectifier detector** consisting of a fine tantalum wire in contact with a mercury pool.

TAPE, MAGNETIC CORE. A toroidal core formed from thin magnetic tape wound in a tight, continuous spiral.

TAPE RECORDER. A device which records information by magnetization of the magnetic particles adhering to a plastic or paper tape.

TAPERED TRANSMISSION LINE. See **waveguide, tapered.**

TAPERED WAVEGUIDE. See **waveguide, tapered.**

TARGET. (1) A substance or object exposed to bombardment or irradiation. A thin target is one of thickness so small that there is negligible energy loss or absorption of the incident particles or photons traversing it. A thick target is one of such thickness that there is appreciable energy loss or absorption of the incident particles or photons traversing it. An infinitely thick target is one of such thickness that there is complete absorption of the incident particles or photons. (2) The anode or anticathode of an **x-ray tube,** from which the x-rays are emitted as a result of electron bombardment (3) The initially stationary atom or nucleus in a **nuclear reaction.** (4) Any object capable of reflecting a **sonar** or **radar** beam. (5) The signal electrode of an **image-dissector tube.**

TARGET STRENGTH. The target strength T, in **decibels** (an acoustic term), is given by

$$T = E - S + 2H,$$

where E = **echo level** in decibels, S = **source level** in decibels, $2H$ = total **transmission loss** in decibels.

TAU. (1) Time (τ). (2) Time constant (τ). (3) Radioactive mean life (τ). (4) Transmittance (τ). (5) Unit vector tangent to path (τ) (6) Decay modulus (τ).

TAYLOR INTERFERENCE EXPERIMENT. G. I. Taylor set up a **diffraction** experiment using light so faint that it was unlikely that there should be two photons in the apparatus at the same time. Very long photographic exposures were required. The diffraction pattern was just the same as that obtained with a strong source of light. This experiment raised an interesting question. Since light energy is concentrated in quanta (**photons**) and only one photon was present at a time, it could go over only one of the two possible paths. Then what did it react with to form a diffraction pattern? **Quantum mechanics** supplies an answer by indicating that the wave properties of light, which allow interference, merely determine the probability of the photon reaching a given location. Hence the photon may be said to interfere with itself.

TAYLOR-OROWAN DISLOCATION. See **dislocation, edge.**

TAYLOR SERIES. See **Taylor theorem.**

TAYLOR THEOREM. The Taylor theorem states that $f(x)$ may be expressed as a finite series in powers of $(x - a)$,

$$f(x) = f(a) + (x - a)f'(a) + \frac{(x - a)^2}{2!}f''(a) + \cdots + \frac{(x - a)^{n-1}}{(n - 1)!} f^{(n-1)}(a) + R_n.$$

The last term, which has several different forms, is the **remainder** after n terms. If the remainder approaches zero as the number of terms increases without limit, the resulting infinite power series is called the Taylof series. In order to expand a given function in such a series, both the function and its derivatives must exist at $x = a$. The theorem may be extended to give a series for functions of two or more variables. (See also the **Maclaurin theorem.**)

TEARING. In television, a synchronizing circuit disruption which causes the displacement of lines from their normal position. The visual effect is as though portions of the image had been physically torn away.

TECHNETIUM. Radioactive element, not found in nature. Symbol Tc. Atomic number 43.

TEE JUNCTION. See **junction, tee.**

TEE, WAVEGUIDE. See **waveguide tee.**

TELECAMERA. Any of the various tubes, such as the **image dissector, orthicon, iconoscope,** which relate an optical image to electrical current.

TELECENTRIC SYSTEM. A telescopic system with the **aperture stop** placed at one of the foci of the **objective lens.** If the aperture stop is placed at the focus on the side of the image, the system is "telecentric" on the side of the image. If the aperture stop is placed on the side of the object, the system is "telecentric" on the side of the object. This is useful in measuring telescopes, since a slight change from exact focus will not greatly change the apparent size of the object.

With a telecentric system, either the **entrance** or the **exit pupil** is at infinity.

TELEGON. Trade name for one type of **selsyn** or **synchro** which, because of its design, does not require moving contacts.

TELEGRAPH REPEATER. A relay inserted at intervals in a telegraph line to amplify the signal. The relay coil is actuated by the weak incoming signal, while the relay contacts and a local battery initiate a strong outgoing signal.

TELEGRAPH SOUNDER. See **sounder.**

TELEGRAPHY. Communication by telegraph, whether the older manual type or the more recent automatic or printing type, is done by a code of electrical pulses. In the manual type the operator sends a certain combination of pulses for each letter of his message and the receiving operator then transcribes them into the characteristic letters. In the more complicated automatic types the sending operator uses a keyboard similar to that of a typewriter, and the equipment transforms the striking of a key into the proper signals (not the same code as for manual operation) and a machine at the receiving end selects the proper letter and the message is typed. The message may be transcribed to a punched tape and then transmitted automatically.

TELEMETER. The measurement of various quantities at a distance by the transmission of a suitable signal by telegraph, telephone or radio. Also the complete equipment used for this purpose.

TELEPHONE RECEIVER. An **earphone** for use in a telephone system. (See **transducer, electroacoustic.**)

TELEPHONE RECEIVER, BIPOLAR. A **telephone receiver** in which the alternating force, due to the alternating current in the electromagnet, operates directly upon a diaphragm armature of steel.

TELEPHONE RECEIVER, CRYSTAL. A **telephone receiver** consisting of a light diaphragm connected to a Rochelle salt crystal. The three corners of a "bender" crystal are fastened to the case. The fourth corner is connected to the diaphragm.

TELEPHONE RECEIVER, DYNAMIC. A **telephone receiver** consisting of a light diaphragm coupled to a **voice coil** and a suitable mechanical network for controlling the **response.**

TELEPHONE RECEIVER, INDUCTOR. A **telephone receiver** in which a straight line conductor, located in a magnetic field, drives a "V"-shaped diaphragm.

TELEPHONE, SOUND-POWERED. See **sound-powered telephone.**

TELEPHONE TRANSMITTER. A **microphone** for use in a telephone system.

TELEPHONY. The science of communicating speech by electrical means over wire circuits. The complete system has at least three fundamental components, the transmitter which converts the sound variations into electrical variations, the transmission circuits and the receiver which converts the electrical variations back into sound.

TELEPHOTO. See **facsimile.**

TELEPHOTOGRAPHY. Photography of distant objects by means of a special, magnifying, camera-objective (telephoto lens). Telephotography has become very important in photographing the ground from high flying aircraft (aerial photography).

TELLER-REDLICH PRODUCT RULE. For two isotopic molecules the product of the frequency ratio $\omega^{(i)}/\omega$ values for all vibrations of a given symmetry type is independent of the potential constants and depends only on the masses of the atoms and the geometrical structure of the molecule. (See O Redlich, *Z. physik. Chem. B.* **28,** 371 (1935))

TELESCOPE. A device which may consist of a single lens or mirror, but frequently is a **telescopic system,** by which distant objects may be observed.

TELESCOPE, CASSEGRAINIAN. See **Cassegrainian telescope.**

TELESCOPE, DAHL-KIRKAM. See **Dahl-Kirkam telescope.**

TELESCOPE EXIT PUPIL (EYE RING). The exit pupil or eye ring of a telescope is the image of the **aperture stop,** commonly the **objective lens,** formed by the **eye lens.** For maximum field of view, the exit pupil of the telescope should coincide with the entrance pupil of the observer's eye. The intersection of the plane of the exit pupil with the optical axis of the instrument is the eye point, i.e., the proper position for the observer's eye. A **Galilean telescope** has a virtual exit pupil, and hence the field of view is restricted.

TELESCOPE, GALILEAN. See **Galilean telescope.**

TELESCOPE, GREGORIAN. See **Gregorian telescope.**

TELESCOPE, NEWTONIAN. See **Newtonian telescope.**

TELESCOPE, REFLECTING. See **reflecting telscope.**

TELESCOPE, REFRACTING. See **refracting telescope.**

TELESCOPIC SYSTEM. A combination of **objective** and **ocular** with which distant objects may be observed visually, photographically or by other detecting means.

TELETYPE. A **telegraph** system which employs a typewriter mechanism for transmission and reception. Pressing a given key at the transmitter initiates a coded signal which causes the corresponding key to be actuated at the receiver.

TELETORQUE. Trade name for a **synchro.**

TELEVISION. Television is the transmission and reception of visual images, either still or motion, by electrical means, commonly by radio, for instantaneous viewing without permanent recording. For a practical system certain fundamental components or functions are necessary:

(1) Camera device to pick up the scene.

(2) Transducer to convert the light impulses of the scene to corresponding electrical pulses.

(3) Transmitter to convert the electrical pulses into proper form to be transmitted to the receiver.

(4) Receiver to pick up the transmitted signals and convert them to the proper form to apply to a transducer.

(5) Transducer to convert the electrical pulses back into light in a reproduction of the original scene.

While in both still and motion pictures the entire scene is utilized at the same time to

produce the film image, in all the present practical systems of television it is necessary to break up the scene into minute elements and utilize these elements in an orderly sequence. This process is called scanning and is very similar to the process of reading line by line the printed page. In reading the eye progresses along the line word by word, relatively slowly, and then returns rapidly to the beginning of the next line, and repeats this process on down the page. In scanning the picture must be broken down into lines of successive elements just as the eye breaks down the printed page into words. While there have been various methods developed for performing this function all those in use at the present time utilize some electrical means. However, since it gives a rather clear idea of the basic process, we might consider one of the earlier mechanical methods using a revolving disk. This disk had a series of small holes along a spiral near its outer edge as shown in Fig. 1. Suppose, now, the picture

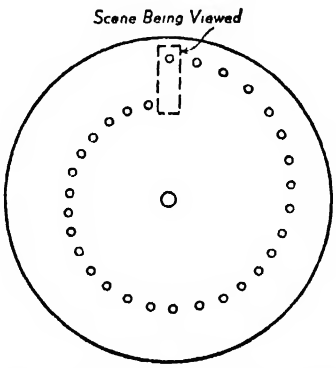


Fig. 1. Mechanical scanning disk

is viewed through these holes as the disk is rapidly revolved. The outermost hole passes across the top of the picture so if the observer is looking through it he sees successively the parts of the picture opposite the hole as it passes across the scene. As the first hole moves beyond the edge of the picture, the second comes to the other edge, and since it is one hole diameter nearer the center of the disk than the first, it covers a second line across the picture. Then the third hole crosses a line just below the second and so on until the disk has made a complete revolution when the entire picture has been covered. This is repeated at the rate of revolution of the disk. If these successive small sections of the picture as seen through the disk can be made to produce corresponding electrical effects the entire picture can be reproduced in an orderly sequence of electrical pulses. When the disk was the standard means of scanning this was accomplished by replacing the eye of the above discussion by a phototube. Modern television, as has been said, utilizes an electrical scanning method.

The received scene must be reconstructed from these electrical pulses, or their received equivalents. If we assume that the original scanner broke the picture down into ten lines and each line had ten elements side by side (this is determined by the width of the hole, being the width of the picture divided by the hole width) then we have 10 times 10 or 100 elements in the scene and our reproduced picture must be built of 100 blocks. It can readily be seen that this would give a very coarse mosaic effect to the picture since each element is fixed in intensity of light. More lines would give more elements and finer detail in the receiver scene. A close comparison may be drawn between this and the printed pictures of newspapers and magazines. The relatively coarse newspaper pictures are lacking in detail while the usual magazine half-tones give very good detail. The difference between these pictures is the number of dots or elements (clearly visible if the printed picture is viewed through a magnifying glass) of which they are composed. Various technical considerations dictate the exact number of lines into which the television scene may be broken, but at present it is of the order of 500, while the future holds promise of much higher numbers and consequently much better detail.

Besides the number of lines per scene, the engineer must decide upon the repetition rate. In moving pictures at present the action effect is produced by projecting upon the screen successive scenes taken and projected at the rate of 24 per sec. The persistence of vision of the eye then gives the effect of smooth motion. The television pictures must also be repeated at a rate high enough to give the illusion of smooth motion. While the motion picture rate of 24 frames per sec would be satisfactory for this the standard power supply frequency of 60 cycles dictates the use of 30 frames per sec for television. Further to improve the quality of the reproduced picture, the scanning is not done for adjacent lines in order, but the picture is scanned over alternate lines first and then scanned again

over those missed the first time. This double scanning, known as interlaced scanning, is done in the thirtieth-of-a-second period of one frame.

A block diagram of a complete television system is shown in Fig. 2. The original scene is focused on the camera tube by a light lens system. The camera tube converts this light picture into the sequence of electrical elements necessary for transmission. (For the operation of two of the various types of camera tube see **iconoscope** and **image dissector.**) The very minute electrical signals coming from the camera tube are amplified by wide band **amplifiers,** the wide band being necessitated by the great range of frequencies produced by the modern multi-line systems. This wide band amplifier feeds a monitor circuit which reproduces the televised scene on a picture tube so the operator can check the camera circuit operation continuously. It also drives the modulator which modulates the picture signals on the radio-frequency **carrier** in a manner very similar to that of the audio **modulation** of conventional broadcasting. The modulated radio frequency is then fed to the **antenna** and radiated into space. At the same time the **microphone** is picking up the sound associated with the scene. This signal is amplified and impressed on the radio frequency sound carrier just as for any amplitude modulated **transmitter.** The sound-modulated carrier is radiated simultaneously with the picture carrier. Both are then picked up by the receiving **antenna,** amplified and fed through the first detector and intermediate frequency amplifiers of a **superheterodyne receiver.** The two types of signal are then separated and each is fed to its proper **detector** or demodulator. The sound signals, now at audio frequency, are further amplified and drive the **loudspeaker.** The picture signal circuits are much more complex. In order to reproduce the scene at the receiver, it is necessary for the receiver transducer, whatever its nature, to follow exactly the operation of the camera tube. Thus when the camera scans the scene at a given rate, each scanning line starting at a definite time after the preceding one, the picture tube must retrace the scene in exactly the same order, each line starting at the same time interval after the preceding one. Otherwise the various lines might get badly skewed or out of synchronism and a badly distorted picture would result. To insure accurate synchronization between the transmitting end and the receiving end, synchronizing pulses are transmitted at the end of each scanning line. In addition synchronizing pulses to govern the

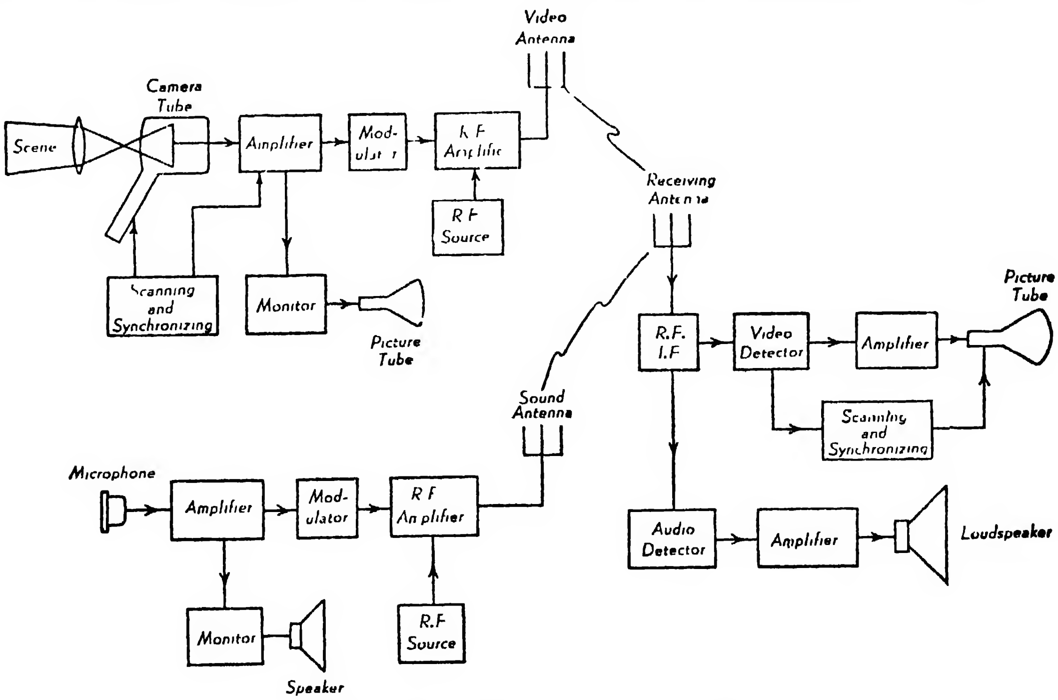


Fig 2 Block diagram of television system

return of the scanning to the top of the scene are also transmitted. These various pulses are impressed on the signal in the transmitter during the short time interval while the scanning is returning from the end of one line to the beginning of the next. In the receiver these synchronizing pulses must be separated from the detected signal and routed into the proper channels. They are then used to synchronize the sweep **oscillators** which give the reversed scanning at the receiver or picture tube. The video signals without the synchronizing pulses are amplified in the proper channels of the circuit and also fed to the picture tube. The electronic picture tube is the **cathode ray tube.** The electron beam issuing from the gun is modulated in intensity by the picture or video signal so the intensity of the fluorescent spot produced by it on the tube screen is a reproduction of the intensity of the corresponding part of the original scene The synchronizing and scanning circuit produces a sweep signal which is applied to the picture tube by plates or coils just as in the oscilloscope discussed in the section on cathode ray tubes. This sweep action carries the electron beam relatively slowly across the screen, then blanks it and returns it rapidly, moves it down and repeats, the time for each operation being the same as for the corresponding operation in the camera tube, the two operations being linked together by the synchronizing pulses After completing the scanning of alternate lines of the picture, the beam is deflected back to the top of the picture and repeats this operation, now filling in the alternate lines which were skipped on the first scanning, again in exact synchronism with the same process in the camera tube It can be seen, then, that since the intensity of the spot corresponds at each instant to the intensity of the original scene and the position of the spot corresponds with the position of the original scanning position at the original scene, the reproduced effect on the screen of the picture tube is the scene which was picked up by the camera.

While the various systems of television in current use are all electronic in nature and differ in details rather than principle, the systems are highly complicated and are subject to certain limitations. The frequency band of the video signal is proportional to the number of lines, the width of the elements in any line and the number of frames per second, giving a band width of several megacycles for satisfactory reproduction. Since this requires a correspondingly wide radio-frequency **channel** it is entirely impracticable to use carrier frequencies in the ordinary broadcast band, both because the entire band could accommodate less than one station, and also because of complications in designing suitable selective circuits at these frequencies. These factors have forced television to the very high frequency region Further to aid in the problem of getting the most out of the available spectrum space, both **sidebands** are not transmitted, but one is eliminated except for the components nearest the carrier. This is known as vestigial transmission and is a compromise between conventional double sideband and single sideband transmission The audio signal band is transmitted on adjacent frequencies, the spectral arrangement being shown in Fig. 3 Because of the nature of propagation at these high frequencies the range of television stations is very limited, reliable reception being possible over distances very little greater than **line-of-sight** distances. Under abnormal atmospheric conditions reception can be secured over greater distances, sometimes even running into hundreds of miles, but this is extremely erratic and occurs only rarely. The reflection and diffraction problems which accompany these high frequencies also enter the problem and limit the satisfactory reception of television. It seems doubtful if reliable reception will be available for years for any but the residents of urban and suburban areas. The conventional chain service of standard broadcasting is also unlikely since the wide band of video frequencies introduces grave problems in wire transmission. The **coaxial cable** is the only possibility for wired program connections and it is very expensive. Automatic relay transmitters and receivers operating on ultra high frequencies offer the possibility of radio-

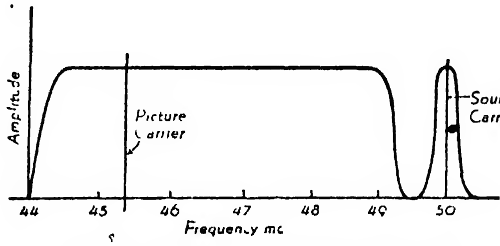


Fig 3. Spectral distribution of signal

linked networks. However, the entire transmitting procedure is so expensive at present it is doubtful if smaller communities will justify the expense so television service for these and rural areas must wait for technical advances to bring down the costs. In spite of these limitations, the service which can be rendered in large population centers is at present satisfactory and within the very near future bids fair to be greatly improved, both by development of systems using more lines and by reduction of the cost of color television.

TELEVISION, DOT SEQUENTIAL, COLOR. A system of color **television** wherein the dots or smallest picture elements are produced in a red, blue, green sequence.

TELEVISION, FIELD SEQUENTIAL, COLOR. A system of color **television** in which the fields are produced in a red, blue, green sequence

TELEVISION, LINE SEQUENTIAL, COLOR. A system of color **television** in which the lines are produced in a red, blue, green sequence.

TELEVISION RECEIVER. A device to receive transmitted **television** signals and convert these signals to the pictures and sounds of the television program.

TELEVISION TRANSMITTER. The aggregate of such radio-frequency and modulating equipment as is necessary to supply to an **antenna system** modulated radio-frequency power by means of which all the component parts of a complete television signal (including **audio, video,** and **synchronizing signals**) are concurrently transmitted.

TELLURIUM. Nonmetallic element Symbol Te Atomic number 52.

TE$_{m,n,p}$ RESONANT MODE (IN CYLINDRICAL CAVITY). See **resonant mode, TE$_{m,n,p}$ (in cylindrical cavity).**

TE$_{m,n}$ WAVE (IN CIRCULAR WAVEGUIDE). See **wave, TE$_{m,n}$ (in circular waveguide).**

TE$_{m,n}$ WAVE (IN RECTANGULAR WAVEGUIDE). See **wave, TE$_{m,n}$ (in rectangular waveguide).**

TEMPERATURE. Fundamentally, temperature is a manifestation of the average translational kinetic energy of the molecules of a substance due to heat agitation, and is measurable by any one of many physical effects due to changes or differences in this energy. Thus, substances expand, their electrical resistivity changes, gases and vapors exert varying pressure, the viscosity of fluids alters, etc., as the temperature varies; and the state of aggregation of any substance (whether solid, liquid, or gaseous), under a fixed pressure, depends primarily upon the temperature. Very imperfectly, also, our special temperature sense is able to judge whether one body with which we come into contact is warmer or colder than another. Heat energy always transfers itself spontaneously from the warmer to the cooler parts of any body or system of bodies, never in the reverse direction, and the transfer ceases when the temperatures become equalized The temperature of a vacuum may be defined as the temperature of a small body placed in it and in thermal equilibrium with it All measurements of temperature, upon whatever principle they are based, are comprised under **thermometry.** (See also **temperature scales.**)

TEMPERATURE, ABSOLUTE. (1) The temperature measured on the thermodynamic scale (2) The temperature measured from the **absolute zero** ($-273.16°C$). Degrees centigrade + 273.16° = degrees absolute. (See **temperature scale, Kelvin,** and **temperature scale, absolute.**)

TEMPERATURE, COLOR. The temperature at which the light from a **complete radiator** matches in **chromaticity** the light from the given source.

TEMPERATURE COLOR SCALE. The relationship between the temperature of an incandescent body or substance, and the color of the light emitted Thus, when metals are heated, a faint red glow becomes perceptible at 500°C, or slightly higher, becoming bright red at around 800°–900°C, and reaching "white" heat at about 1500°C.

TEMPERATURE, CORRELATED COLOR. The color temperature (see **temperature, color**) of a source where the **black body chromaticity** not only matches the source, but is as similar as possible to it.

TEMPERATURE, CRITICAL. That temperature above which a gas cannot be lique-

fied by application of any pressure, however great. The following are the critical temperatures of some common substances (in degrees centigrade):

Carbon dioxide	31.1
Ammonia	132.9
Ether . . .	190
Water . . .	374
Nitrogen	−147.1
Oxygen . .	−118.8

TEMPERATURE GRADIENT. The temperature gradient, which determines the direction of heat flow by **thermal conduction,** is directed normally to the **isothermal** (3) surfaces. Its magnitude is the space rate of change of temperature in this direction, i.e.,

$$|\nabla t| = \lim_{\Delta s \to 0} \frac{t_2 - t_1}{\Delta s},$$

where t_1 and t_2 are the temperatures on two isothermal surfaces separated by a distance Δs. In many cases of linear heat flow, the value of $(t_2 - t_1)/\Delta s$ is independent of Δs and the **average** temperature gradient is identical at any point.

TEMPERATURE GRADIENT IN THE ATMOSPHERE. The maximum rate of decrease of temperature with distance in the atmosphere is known as the thermal gradient. Temperature gradients directed vertically are known as lapse rates.

TEMPERATURE, LUMINANCE. For any source of radiation, the luminance temperature is that of a **complete radiator** which has the same **luminance** for a specified wavelength (or in practice, for a specified narrow spectral region).

TEMPERATURE (T^*), MAGNETIC. See **magnetic thermometer.**

TEMPERATURE, NEUTRAL. The temperature at which the electromotive force produced by heating one junction of a **thermocouple** the other junction being constant at 0°C, reaches a maximum. Above this temperature the electromotive force steadily decreases until it reaches a zero value. The latter point is called the temperature of inversion. For an iron copper couple the neutral temperature is 275°C and the temperature of inversion 550°C.

TEMPERATURE, POTENTIAL. See **potential temperature.**

TEMPERATURE, RADIATION. For any source of radiation, the radiation temperature is that of a **complete radiator,** which has the same total radiant emittance. (See **emittance, total radiant.**)

TEMPERATURE, REVERSAL. See **reversal temperature.**

TEMPERATURE SATURATION. The condition which exists in a thermionic electron tube when the **space current** (for a given set of electrode voltages) cannot be increased by further increase of cathode temperature. The tube is said to be space-charge limited when operating in the region of temperature saturation.

TEMPERATURE SCALE, ABSOLUTE. Any temperature scale whose zero is the absolute zero of temperature, −273.16°C or −459.7°F. The most commonly used scale is the Kelvin scale, but the Rankine scale is also employed. (See **temperature scale, Kelvin; temperature scale, Rankine.**)

TEMPERATURE SCALE, CELSIUS. A temperature scale based on the mercury-in-glass thermometer, with the freezing point of water defined as 0°C and the boiling point defined as 100°C, both under conditions of normal atmospheric pressure. Often called the Centigrade scale. (See also **thermometry;** and **Introduction.**)

TEMPERATURE SCALE, CENTIGRADE. The older name of the Celsius temperature scale in the English-speaking countries. Officially abandoned by international agreement in 1950, but still in common use. (See also **thermometry.**)

TEMPERATURE SCALE, FAHRENHEIT. A temperature scale based on the mercury-in-glass thermometer, with the freezing point of water defined as 32°F and the boiling point as 212°F, both under conditions of normal atmospheric pressure. (See also **thermometry.**)

TEMPERATURE SCALE, INTERNATIONAL. A scale of temperature fixed by international agreement. Between −190°C and +660°C, it is based upon the resistance of a standard platinum resistance thermom-

eter in accordance with the following formulas for resistance at temperature t:

Below 0°C:

$$R_t = R_0[1 + At + Bt^2 + C(t - 100)t^3]$$

Above 0°C:

$$R_t = R_0(1 + At + Bt^2)$$

where A, B, C are empirical constants. From +660°C to the **gold point,** it is based upon the platinum-platinum rhodium **thermocouple**, and beyond this upon the **optical pyrometer.**

TEMPERATURE SCALE, KELVIN. A thermodynamic temperature scale based upon the efficiency of a reversible heat engine, operating in cycles between two heat reservoirs. The temperatures of the two reservoirs are in the same ratio as the quantities of heat transferred between the reservoirs and the machine. In this manner the temperature ratio becomes independent of the working substances. To fix the temperature values themselves, zero on this scale is defined as that temperature of the heat sink at which the efficiency of the heat engine is 100%. The scale may be identified with the ideal gas scale by defining the size of the degree to be the same in both cases, and by defining the ice point on the Kelvin scale as occurring at 273.16 degrees. (See **Carnot cycle** and **thermometry.**)

TEMPERATURE SCALE, RANKINE. An absolute temperature scale on which the difference of the boiling and freezing points of water is 212° and the zero of which is the absolute zero of temperature. The freezing point of water, under normal atmospheric pressure, is at 491.7°R. One degree Rankine (°R) = one degree Fahrenheit (°F). (See also **thermometry.**)

TEMPERATURE SCALE, THERMODYNAMIC. See discussion of **thermometry.**

TEMPERATURE, STANDARD. In general, a temperature established by some unvarying process, such as a melting or boiling point or pressure or volume of a substance under fully-defined conditions. In common use, the term is applied to the temperature of a mixture of pure ice and water when the pressure on the water surface is one atmosphere. This is the temperature of 0° on the Celsius scale, or 273.16° on the Kelvin scale.

TEMPERATURE, TRANSITION (TRANSITION POINT). That temperature at which one phase of a complete heterogeneous **equilibrium** disappears, and another phase takes its place. Thus the melting point of a homogeneous solid or the boiling or freezing points of a homogeneous liquid, are transition points. The term is most widely used, however, for the particular case of transition between two solid states of a **polymorphic** substance. It is the temperature at which two forms, commonly crystalline, can coexist in equilibrium, whereas above or below that temperature only one form or the other, respectively, are stable.

TEMPERATURE, VIRTUAL. See **virtual temperature.**

TENSILE STRENGTH. The resistance offered by a material to tensile stresses, as measured by the tensile force per unit cross-sectional area required to break it.

TENSIMETER. An apparatus used to determine transition points (see **temperature, transition**) indirectly by measuring small changes in vapor pressure.

TENSIOMETER. An apparatus for measuring the **surface tension** of a liquid by registering the force necessary to detach a metal ring from the surface.

TENSIOMETER METHOD. See **surface tension, methods of measurement.**

TENSION A force, usually in a wire, string or rod, supporting a weight or otherwise stretched between two points. (See also **tension, surface.**)

TENSION, SURFACE. See **surface tension.**

TENSOR. A set of n^r **components** which are functions of the coordinates of any point in n-dimensional space. They transform linearly and homogeneously, according to certain rules, when a transformation of coordinates is made. Tensors are called **covariant, contravariant,** or **mixed,** according to the law of transformation. The number r is called the **rank or order** of the tensor.

TENSOR CONTRACTION. Suppose two indexes in a **tensor,** one upper and one lower, are identical, $A^m{}_{npm}$. Then summation over

the repeated index shows that the tensor is actually of lower rank, for its transformation law is

$$\bar{A}^m{}_{npm} = \frac{\partial \bar{x}^m}{\partial x^i} \frac{\partial x^j}{\partial \bar{x}^n} \frac{\partial x^k}{\partial \bar{x}^p} \frac{\partial x^h}{\partial \bar{x}^m} A^i{}_{jkh}$$

$$= \frac{\partial x^j}{\partial \bar{x}^n} \frac{\partial x^k}{\partial \bar{x}^p} \delta_i{}^h A^i{}_{jkh} = \frac{\partial x^j}{\partial \bar{x}^n} \frac{\partial x^k}{\partial \bar{x}^p} A^i{}_{jki},$$

where $\delta_i{}^h$ is a **mixed tensor** The result could properly be written A_{jk} since the tensor transforms like a **covariant** tensor of rank two. The process of **contraction,** which can be used for tensors of any rank, thus consists of deleting a repeated upper and lower index.

TENSOR, CONTRAVARIANT. Suppose $(x^1, x^2, \cdots, x^n)$ are the coordinates of a point referred to a given coordinate system in n-dimensional space and $(\bar{x}^1, \bar{x}^2, \cdots, \bar{x}^n)$ are the coordinates of the same point referred to another coordinate system. Then n quantities $(A^1, A^2, \cdots, A^n)$, functions of these coordinates, are the **contravariant** components of a **tensor** of rank one if they transform as follows:

$$\bar{A}^i = \frac{\partial \bar{x}^i}{\partial x^r} A^r; \quad i = 1, 2, \cdots, n.$$

The summation for the dummy **index** r is understood and the upper suffix is not an exponent but a means of designating the different components. Contravariant tensors of higher rank are defined in a similar way. Thus, for a tensor of rank two

$$\bar{A}^{ij} = \frac{\partial \bar{x}^i}{\partial x^r} \frac{\partial \bar{x}^j}{\partial x^s} A^{rs}.$$

A tensor of rank zero is a **scalar;** of rank one, a **vector.**

TENSOR, COVARIANT. See **tensor, contravariant.** The transformation laws are

$$\bar{A}_i = \frac{\partial x^r}{\partial \bar{x}^i} A_r;$$

$$\bar{A}_{ij} = \frac{\partial x^r}{\partial \bar{x}^i} \frac{\partial x^s}{\partial \bar{x}^j} A_{rs}$$

for **covariant** tensors of rank one and two, respectively, the meaning of x^r, x^i, etc., being the same as in the entry on **tensor, contravariant.** Note that subscripts are used for the components of a covariant tensor and superscripts for those of a contravariant tensor.

TENSOR, CURVATURE. See **Riemann-Christoffel tensor.**

TENSOR DIFFERENTIATION. Differentiation of a **covariant** tensor does not yield a tensor, for the derivative does not transform properly. The covariant derivative of a covariant tensor of rank one is then defined as

$$A_{i,j} = \frac{\partial A_i}{\partial x^j} - \{ij,h\} A_h$$

where $\{ij,h\}$ is a **Christoffel three-index symbol** (not a tensor) and this function transforms like a covariant tensor of rank two. Derivatives of **contravariant** and **mixed tensors** of all ranks may be defined in a similar way.

TENSOR, ENERGY-MOMENTUM. See **energy-momentum tensor.**

TENSOR FORCE. Non-central spin-dependent force between neutron and proton, of the type of an interaction between **magnetic dipoles,** postulated to account for the observed values of the deuteron magnetic moment and electric **quadrupole moment.** (See also **nuclear forces.**)

TENSOR, MIXED. See **tensor, contravariant.** The transformation law for a mixed tensor of second rank is

$$\bar{A}_j{}^i = \frac{\partial \bar{x}^i}{\partial x^r} \frac{\partial x^s}{\partial \bar{x}^j} A_s{}^r.$$

Mixed tensors of higher rank may be defined by analogy. An important mixed tensor is similar to the **Kronecker delta,**

$$\delta_n{}^n = 1, \; \delta_n{}^m = 0, \; m \neq n.$$

It transforms properly for

$$\bar{\delta}_n{}^m = \frac{\partial \bar{x}^m}{\partial x^i} \frac{\partial x^j}{\partial \bar{x}^n} \delta_j{}^i$$

$$= \frac{\partial \bar{x}^m}{\partial x^i} \frac{\partial x^i}{\partial \bar{x}^n} = \frac{\partial \bar{x}^m}{\partial \bar{x}^n} = \delta_n{}^m.$$

TENSOR, SKEW SYMMETRIC. If $A^{ij} = -A^{ji}$ are components of a **tensor,** the tensor is said to be **skew-symmetric.** The property is unaltered upon transformation to another coordinate system.

TENSOR, SYMMETRIC. If the components of a **tensor** satisfy the relation $A^{ij} = A^{ji}$, the tensor is **symmetric.** If the components are neither symmetric nor skew-symmetric, they may always be expressed as $A^{ij} = S^{ij} + T^{ij}$, where $S^{ij} = \frac{1}{2}(A^{ij} + A^{ji})$ which is a symmetric tensor and $T^{ij} = \frac{1}{2}(A^{ij} - A^{ji})$ which is skew-symmetric.

TENTH-POWER WIDTH. In a plane containing the direction of the maximum of a **lobe,** the full angle between the two directions in that plane about the maximum in which the **radiation intensity** is one-tenth the maximum value of the lobe.

TERBIUM. Rare earth metallic element. Symbol Tb. Atomic number 65.

TERM, ENERGY STATE. The energy states of an atom are called S, P, D, F, $\cdots$ terms, respectively, corresponding to the values 0, 1, 2, 3, $\cdots$ of L, the resultant angular momentum **quantum number** of the atom. The energy states of a molecule are called Σ, Π, Δ, Φ $\cdots$ terms, respectively, corresponding to the values 0, 1, 2, 3 $\cdots$ of Λ, the electronic orbital angular momentum (about internuclear axis) quantum number.

The letters indicating the value of L are usually preceded by a superscript denoting the **multiplicity** and followed by a subscript denoting the total angular momentum quantum number J. In addition, the principal quantum number is often written as a coefficient. Thus, in the diagram on page 302, the second triplet state of the mercury energy levels is the

$6\,{}^3P_2$, indicating that $N = 6$,

$$L = 1, S = (3 - 1)/2 = 1, J = 2.$$

TERMINAL. A point at which any **element** may be directly connected to one or more other elements.

TERMINAL PAIR. An associated pair of accessible **terminals,** such as input pair, output pair, and the like.

TERMINATOR, LONGITUDINAL FIN. A thin dissipative strip inserted in a waveguide to act as a **matched load.**

TERMINATOR, PLUG-TYPE. A piece of suitably-shaped, high-loss **dielectric** placed in a waveguide to act as a **matched load.**

TERNARY FISSION. See **fission, ternary.**

TESLA COIL. A type of **induction coil** in which the primary has a high-frequency spark gap instead of the usual interrupter, and whose secondary yields an intense high-frequency discharge. A typical arrangement is shown in the figure. A high-voltage trans-

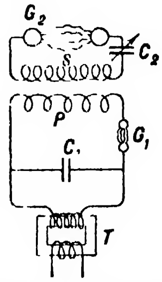


Diagram of Tesla-coil circuits

former T, or sometimes an ordinary induction coil, sends sparks across the primary gap G_1, which is in circuit with a condenser C_1 and the primary air-core coil P, composed of a few turns of heavy copper wire or tubing. Because of the oscillatory nature of the condenser discharge, this circuit is the seat of powerful high-frequency oscillations. The secondary, S, consists of many turns of fine wire. The secondary circuit may be "tuned" by means of a variable condenser C_2, and when it is in **resonance** with the primary, the oscillations in it are very intense. A torrent of high-frequency sparks plays across the secondary gap G_2; or one terminal may be grounded and sparks drawn from the other.

"TESSAR" LENS. See **camera lenses.**

TEST PATTERN. In television, a special chart on which lines and other detail are so arranged as to indicate certain characteristics of the system through which the **television signal** obtained from this chart passes.

TETRADIC An **operator,** related to **tensors** of the third rank, which transforms one **dyadic** into another. Thus, in three dimensions, the tetradic $\mathfrak{J}$ has 81 components and its operation on a dyadic $\mathfrak{A}$ is such that $\mathfrak{J} : \mathfrak{A} = \mathfrak{B}$, where $\mathfrak{B}$ is a dyadic. Tetradics are obtained from tensors by modification of the scale factor so that the dimensionality is unchanged upon transformation. (See **dyadic.**)

TETRATOHEDRAL CRYSTALS. That class of **crystal symmetry** which has only one quarter of the maximum number of faces allowed

by the **crystal system** to which the class belongs.

TETRAHEDRAL ATOM. A configuration of atoms with a valence of 4 in which the valence bonds are directed from the center of a regular tetrahedron, representing the location of the atom under consideration, to the four corners, representing the location of the nearest neighbors.

TETRODE. A four-electrode **electron tube** containing an anode, a cathode, a control electrode, and one additional electrode that is ordinarily a grid

THALLIUM. Metallic element Symbol Tl Atomic number 81.

THALOFIDE (CELL). A **photoconductive cell** using a compound of thallium, oxygen and sulfur as the sensitive element. Useful only in the very near infrared.

THAW-MELT METHOD. A method of obtaining accurate thermal data needed in the study of equilibria between solid and liquid **phases** of systems containing two or more **components.** The finely-divided solid of known composition is heated slowly in a glass tube and is pressed from time to time to expel the first drops of liquid as soon as they are formed, giving the "thaw point" or the temperature at which fusion commences (the point on the solidus curve) Then slow heating is continued until the solid melts completely, giving the "melt point," or the temperature at which the solid phase disappears (the point on the liquidus curve).

THEODOLITE. An instrument used, particularly in surveying, for measuring horizontal or vertical angles

THERM. A unit of heat equivalent to 1,000 large **calories** used in expressing the calorific value of feeds.

THERMAL. Of or pertaining to heat, as thermal capacity, thermal conductivity.

THERMAL AGITATION NOISE. Thermal-agitation noise is due to the random (Brownian) movement of the electrons within a conductor. The noise voltage introduced into a circuit by this cause may be calculated from the equation

$$\overline{e^2} = 5.49 \times 10^{-23} TZdf$$

where $\overline{e^2}$ is the mean-square, thermal-agitation voltage, T is the absolute temperature of the conductor in °K, Z is the resistance of the conductor, or the resonant impedance of a tuned circuit, df is the frequency bandwidth factor. Thermal agitation noise is also called "Johnson" noise

THERMAL CAPACITY. See **heat capacity.**

THERMAL COLUMN. A column of **moderator** extending through the shield of a **reactor** to provide a source of thermal neutrons external to the shield.

THERMAL CONDUCTANCE. See **thermal conductivity; thermal conduction.**

THERMAL CONDUCTION. Every substance is in some measure a conductor of heat, though liquids are generally poor conductors and gases almost non-conductors. The best conductors are metals The flux of heat through a layer of any substance by conduction is proportional to the temperature gradient (fall of temperature per unit thickness), and to a factor called the "thermal conductivity" of the substance, defined as the quantity of heat transmitted per unit time per unit cross section per unit temperature gradient. The thermal conductivities of a few solids are given below, in calories per cm per sec per °C, at room temperature.

Aluminum	0 480	Iron (cast)	0 161
Copper	.918	Lead	.083
Cork	.0001	Paraffin	.0006
Glass	002	Quartz	0.033 or 0 017
Ice	005	Silver	1.006

(It will be noted that quartz, a highly birefringent crystal, has different conductivities along and perpendicular to its optic axis, as do such crystals in general)

The mechanism of thermal conduction is probably at least three-fold. Thermally agitated atoms and molecules doubtless actually jostle each other and thus mechanically pass along the heat energy. Thermal radiation between neighboring atoms or molecules should have a similar result. But neither of these explains the enormous difference in conductivity between, say, copper and glass, both of

which are dense, fine-grained solids; or between silver and lead, both soft, crystalline metals of similar chemical properties. If, however, we examine the electric conductivity of these substances (see **electric conduction and resistance**), we discover that good thermal conductors are also good electrical conductors, and we are led to suspect that thermal as well as electrical conduction may depend upon the activity of electrons. The relationship is brought out quantitatively by the **Wiedemann-Franz law.**

The speed with which a temperature wave progresses by thermal conduction depends upon the "thermal diffusivity" of the conductor, which is its thermal conductivity divided by its **heat capacity** per unit volume.

THERMAL CONDUCTION IN SOLIDS. In metals, heat is transported mostly by the **free electrons**, which are also responsible for the conduction of electricity The relation between the **electrical conductivity** and the thermal conductivity is expressed by the **Wiedemann-Franz ratio,** whence it follows that the conductivity should be nearly independent of temperature at high temperatures; it varies as $1/T^2$ at low temperatures, until it is limited by the **residual resistance** due to impurities and imperfections. In electrical insulators the conduction is by means of **lattice vibrations** or **phonons**, which are scattered by crystalline imperfections, or which interact with one another in such a way as to limit the conductivity. In the absence of imperfections the conductivity should be inversely proportional to the absolute temperature at high temperatures, but according to Peierls' theory of **Umklapp-prozessen** it should increase roughly as $e^{\Theta/2T}$ (where Θ is the **Debye temperature**) as the temperature is lowered, until it is limited by **boundary scattering.**

THERMAL CONDUCTIVITY, COEFFICIENT OF. The time rate of heat conduction per unit area, per unit temperature gradient.

THERMAL CONDUCTIVITY OF GASES, LOW PRESSURE. The elementary theory of **thermal conductivity of gases** does not apply at low pressures, where the **mean free path** becomes of the same order as the dimensions of the apparatus. In the case when the mean free path is much larger than the distance separating the plates between which the heat is transported, it can be shown that the net heat transferred per second per unit area is

$$Q = \tfrac{1}{3}\rho\bar{c}C_v(T_2 - T_1)f$$

where ρ is the density, $\bar{c}$ the mean velocity of the molecules, C_v the specific heat at constant volume for 1 g, $(T_2 - T_1)$ the temperature difference and f, a numerical factor. Q, therefore, depends upon the temperature difference and not the temperature gradient, and is proportional to the pressure. These facts are confirmed by experiment, and the latter property is the basis of a method of measuring low pressures **(Pirani gauge)**. For the meaning of f, see **accommodation coefficient.**

THERMAL CONDUCTIVITY OF GASES, THEORY. From elementary kinetic theory, by considering the number of molecules crossing a plane per second, it can be shown that the thermal conductivity of a gas is given by

$$K = \tfrac{1}{3}\rho\lambda\bar{c}C_v$$

where K is the thermal conductivity, ρ the density, λ the **mean free path,** $\bar{c}$ the mean velocity of the molecules (see **molecular velocity, mean**), and C_v the **specific heat at constant volume** for 1 g. This formula indicates that K is independent of the density (and therefore the pressure), since $\rho \propto 1/\lambda$. This is confirmed by experiment over a moderate range, but the absolute values differ from those given by the above equation by a factor of about 2. A more defined theoretical treatment introduces a factor of about 1.5, giving a closer agreement with experiment. The equation does not hold even qualitatively at high or low pressures.

Values of the thermal conductivity may be used to deduce the mean free path, and hence molecular diameter, since

$$\lambda = \frac{A}{\pi n\sigma^2}$$

where n is the number of molecules per unit volume, σ, the molecular diameter, and A, a numerical factor not very different from unity, which can be evaluated theoretically.

A similar theoretical treatment may be applied to the viscosity of gases. Combination of the results gives the relation $K/\eta = C_v$ where η is the viscosity. This relation is obeyed well, provided that a further numerical factor f is introduced, giving $K/\eta = fC_v$.

THERMAL CONDUCTIVITY OF METALS, DIRECT METHODS. These methods consist in the production of a steady flow of heat along a uniform bar of the metal, and measurement of the temperature gradient. The usual formula is then applied:

$$Q = KA\frac{dT}{dx}$$

where Q is the rate of heat flow, A the area of cross section, and dT/dx the temperature gradient This assumes no loss of heat from the sides of the bar.

One end of the bar is heated electrically by a resistance coil. In the earlier methods, the other end was cooled by passing a stream of water through a spiral tube in good thermal contact with the bar The temperature distribution may be determined by means of thermocouples attached at various points, and hence the temperature gradient found. Heat loss from the sides is minimized by careful lagging, and residual heat loss determined at any temperature by heating the bar uniformly, and then measuring its rate of cooling.

The temperature range and accuracy of the method have been increased by using smaller specimens, enclosed in a metal vacuum-jacket, with the cold end in good thermal contact with a heat sink at constant temperature. The apparatus may be immersed in a **Dewar vessel,** and measurements made down to the temperatures of liquid helium (~2°K). The temperature difference between points a known difference apart may be measured with suitable resistance or gas thermometers.

THERMAL CONDUCTIVITY OF METALS, ELECTRICAL METHOD. A method originated by Kohlrausch in 1900, in which the metal specimen is heated by the passage through it of an electric current, and the temperature distribution along the specimen measured. In the steady state, the heat generated in an element of the specimen by the passage of the electric current is equal to the heat lost by conduction along the rod, assuming no heat loss from the surface. Using this fact, an expression may be derived containing constants which can be evaluated under various experimental conditions, and yielding a value of the *ratio* of thermal to electrical conductivity

THERMAL CONDUCTIVITY OF METALS, JAEGER AND DIESSELHORST METHOD. An accurate application of the electrical method (see **thermal conductivity of metals, electrical method**) to many metals at 18°C and 100°C, in which two ends of the cylindrical specimen were kept in constant-temperature baths at the same temperature. The theory then gives the simple expression

$$\frac{K}{\sigma} = \frac{1}{8}\frac{(V_3 - V_1)^2}{T_2 - T_1}$$

and the ratio K/σ of thermal to electrical conductivity could then be determined by measurement of the potential difference $(V_3 - V_1)$ between the two ends of the bar, and of the temperature difference $(T_2 - T_1)$ between the middle and the ends The heat loss was made definite by surrounding the specimen with a double-walled copper case, through which water or steam was passed, and a correction for it was worked out Jaeger and Diesselhorst also showed that effects due to a radial temperature gradient, caused by this heat loss, were negligible.

THERMAL CONDUCTIVITY OF METALS, MEISSNER METHOD. An application of the electrical method (see **thermal conductivity of metals, electrical method**) for copper down to 20°K. The specimen is contained inside an evacuated, thin-walled constantan tube, a correction for the current flowing through this tube being made The ratio of thermal to electrical conductivity is determined by measuring the resistance of the specimen and the potential difference between its ends with two different currents The ends are kept at the same constant temperature as in the method of Jaeger and Diesselhorst. The necessary modification for this case, where the temperature of the middle of the rod is not measured directly, was made by Diesselhorst.

THERMAL CONVECTION. The transfer of heat by the automatic circulation of a fluid (liquid or gas) due to differences in temperature and density. While water and liquids generally are poor conductors, a kettle of water is quickly heated throughout by applying heat at the bottom. The warmer water, being less dense, is compelled to rise by the colder, which, sinking to the bottom, is warmed in its turn. The process is more

clear-cut when a definite circuit is provided, as in the heating coil attached to a hot-water tank or radiator system. Gasoline engines are cooled by a similar circulation, either entirely automatic or augmented by a small rotary pump. Gases likewise exhibit convection. A chimney "draws" when the air inside it is warmer than that outside, so that the greater pressure difference outside forces the air inward at the bottom. (The term "draw" is manifestly misleading.) The motion of the air in hot-air furnaces and in the **winds** of the atmosphere are good examples.

THERMAL CROSS SECTION. The **cross section** as measured with thermal neutrons. (See **neutron, thermal.**)

THERMAL DEGREE. See **temperature scales.**

THERMAL DETECTOR. A device which utilizes the ability of a radio-frequency current, voltage, or field to change the electrical characteristics of the device as a result of heating. The **barretter, thermocouple** and **thermistor** may be used as thermal detectors.

THERMAL DIFFUSION. The phenomenon by which a temperature gradient in a mixture of two or more fluids tends to establish a concentration gradient. In a binary isotopic mixture in which a steady state temperature gradient is established, and in which there is no convective flow, the equilibrium distribution is given by

$$\left(\frac{N_1}{1 - N_1}\right) T^{-\alpha_T} = \text{const.}$$

Here N_1 is the mole fraction of the component, and α_T is the thermal diffusion constant, related to the thermal diffusion coefficient D_T by

$$D_T = \alpha_T N_1(1 - N_1)D_{12}$$

where D_{12} is the ordinary diffusion coefficient. For isotopic mixtures, α_T is substantially independent of concentration. It is also, within wide limits, independent of pressure, and has no strong dependence on temperature.

THERMAL DIFFUSION METHOD. See **separation of isotopes, thermal diffusion method.**

THERMAL DIFFUSION RELAXATION. A source of **internal friction** in solids. Heat generated at one point of the material by rapid compression diffuses into other regions before the strain is relaxed, and hence is irreversibly lost.

THERMAL DIFFUSIVITY. The quantity $K\rho/C_v$, where K is the **thermal conductivity,** ρ is the density, and C_v is the **specific heat** per unit mass. The magnitude of this quantity determines the rate at which a body with a non-uniform temperature approaches equilibrium.

THERMAL EFFICIENCY. Output, in heat units, divided by the heat supplied or chargeable.

THERMAL ENERGY. See **heat energy.**

THERMAL EQUATOR. The belt of maximum temperature surrounding the earth which moves north and south with (but lagging) the sun's motion. It is also spoken of as the center of the area bounded by the yearly mean isotherms of 80°F.

THERMAL EXCITATION. The acquisition of excess energy by atoms or molecules by collision processes with other particles.

THERMAL EXPANSION OF SOLID. As a consequence of the **anharmonic terms** in the potential energy of a solid, when the atoms have large amplitudes of thermal vibration their average positions tend to move apart. It can be shown that the expansion coefficient is nearly constant at high temperatures (see **Grüneisen's constant**), whilst at low temperatures a relation of the form

$$\delta V \propto \delta U$$

holds, where δV is the change in volume from the absolute zero and δU is the thermal energy of the lattice.

THERMAL GRADIENT IN THE ATMOSPHERE. See **temperature gradient in the atmosphere.**

THERMAL LUMINESCENCE. See discussion under **luminescence.**

THERMAL NEUTRON. See **neutron, thermal.**

THERMAL RADIATION. All bodies that are not at absolute zero emit radiation excited by the thermal agitation of their molecules or atoms, whether there are other causes of **excitation** or not. This thermal radiation ranges in wavelength from the longest **infra-red to**

the shortest **ultra-violet** rays, its **spectral energy distribution,** however, depending upon the nature of the body and upon its temperature. The total emissive power of a surface at any temperature is the rate at which it emits energy of all wavelengths and in all directions, per unit area of radiating surface. The flux density (per unit solid angle) in various directions obeys the **cosine emission law** approximately; but strictly only in the case of a **black body.** Thermal radiation is observed and measured by means of different types of **radiometer,** by the **bolometer,** and by the **radiomicrometer;** also, in the shorter wavelengths, by its photographic and photoelectric effects.

Many of the properties of thermal radiation can be derived on a **thermodynamic** basis (e.g., the **Stefan-Boltzmann law** and the first **Wien law**). The more complete theory, however, demands the use of the **electromagnetic theory of light** and of the methods of **statistical mechanics,** to which must be added the **quantum** hypothesis When all of these are combined the **Planck radiation formula** results as the best description of thermal radiation.

THERMAL SHIELD (NUCLEAR REACTOR). A high density heat-conduction portion of a **shield** placed close to the reflector Its function is to remove a major portion of the energy carried by the radiation emanating from the core.

THERMAL SIPHON. A closed loop containing fluid, a vertical member of which is kept at a different temperature from that of another vertical member. In this way circulation is established without the use of a pump.

THERMAL UTILIZATION. The probability that a thermal neutron which is absorbed is absorbed usefully; usually used to describe the probability that a neutron is absorbed in a fissionable material.

THERMAL UTILIZATION FACTOR. In a nuclear **reactor,** the ratio of thermal neutrons (see **neutron, thermal**) absorbed in fuel to the total thermal neutrons absorbed.

THERMAL VELOCITY OF CHARGE. Electrons emitted from the cathode of a **thermionic electron tube** have initial velocities characteristic of their thermal energy. That is, there is a **Maxwellian velocity distribution** (but not characteristic of cathode temperature, because of the energy loss (**work function**) in escaping).

THERMAL VIBRATION OF CRYSTAL LATTICE. The assembly of atoms bound together by local interatomic forces to make up a **crystal lattice** is capable of vibrating in a large number of independent **normal modes** about the static equilibrium configuration. In these vibrations is stored a large proportion of the thermal energy of the solid, and hence the major contribution to the **specific heat.** The vibrational energy is quantized, so that there is some **zero-point motion** even at 0°K, and the energy of each mode may only increase in multiples of $h\nu$, where ν is the frequency and h, **Planck's constant.** The exact frequency spectrum cannot easily be calculated (although it may be observed by **X-ray** and **neutron diffraction**) but the **Debye theory,** which treats the lattice as an elastic continuum with a limited number of degrees of freedom, is usually a good approximation.

The thermal vibrations are important in all theories of **electrical conductivity, thermal conductivity, infrared absorption,** etc. (See also **phonon.**)

THERMAL WAVES. See **long waves in the prevailing westerlies.**

THERMALIZATION (OF NEUTRONS). Reduction of the kinetic energy of neutrons, as by repeated collisions with other particles, to a point where they have approximately the same kinetic energy as the atoms or molecules of the medium in which the neutrons are undergoing elastic scattering. Since this atomic or molecular energy is thermal in origin, being a direct temperature function, the neutrons whose energies have been so reduced are called thermal neutrons, and the process thermalization.

THERMEL. The well-known Seebeck effect (see **thermoelectric phenomena**) is the principle underlying a large class of thermoelectric thermometers. The essential feature is a circuit composed of two different metals, the two junctions of which are at different temperatures, and in which a net electromotive force develops as a result of this temperature difference. Any device which uses this electromotive force, or the current due to it, as a measure of temperature is called a thermel (a term introduced by W. P. White).

The simplest form is a **thermocouple,** composed of two pieces of metal, or wires, soldered or welded together at their ends, the other ends being connected to a **galvanometer** or a **potentiometer.** Various pairs of metals are used, for example, antimony and bismuth, copper and iron, or copper and constantan (an alloy of copper and nickel). High-temperature thermocouples are commonly of platinum, with some other refractory metal such as iridium or an alloy of platinum and iridium, rhodium or chromium. One of the junctions may be enclosed in a protecting tube, the other being kept at zero by means of melting ice or at another reference temperature. In cases where a temperature difference only is desired, the two copper or platinum lead-wires may be attached to the opposite ends of a single wire of the other metal, and the two junctions placed at the two points to be compared.

THERMION. The charged particle, either negative or positive, emitted by a body in the process of thermionic emission. (See **thermionic emission;** also **thermionic phenomena.**)

THERMIONIC CATHODE. See **cathode, thermionic.**

THERMIONIC EMISSION. Electron or ion emission due to the temperature of the emitter. By heating a metal, it is possible to "evaporate" electrons from it. This agrees with the ideas of the **free electron theory of metals,** where the electrons are treated as a gas imprisoned within the lattice of ions. Heating the gas increases the number of electrons which have sufficient energy to cross the **potential barrier** at the surface and hence increases the current. (See **Richardson equation.**) Thermionic emission is very sensitive to the state of the surface.

THERMIONIC EMISSION, LAW OF. See **Richardson-Dushman equation.**

THERMIONIC GRID EMISSION. See **grid emission, thermionic.**

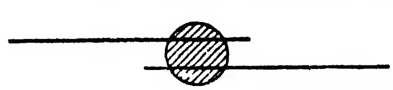
THERMIONIC PHENOMENA. In view of the commotion among the atoms and electrons of a heated substance, it is not surprising that electric particles, both positive ions and electrons, should be projected from a highly heated body. If the body is electrically charged, particles of the same sign as the charge, when once through the surface barrier (see **work function**), are repelled into the surrounding space, where they can be detected. Electric particles thus emerging, either positive or negative, are called thermions The heated body may be a filament of pure metal, electrically heated, or a layer of some chemical substance spread over and heated by such a filament. The usual experimental arrangement is to enclose the thermionic emitter as an electrode in a tube or bulb, along with another electrode of opposite sign, so that the field between the two will set up a stream of the released thermions, called a thermionic current. With sufficient voltage, this current reaches a maximum or "saturation" value, the ions being then swept away as fast as they are released.

In the early experiments of Becquerel, Guthrie, Edison, Elster and Geitel, and others, it was found that at lower temperatures (up to a red heat) the thermionic emission from metals is predominantly positive, but that at much higher temperatures (white heat) the negative or electronic emission rapidly surpasses the positive and becomes all-important. The positive emission from a pure metal like platinum or tungsten appears to be due to impurities such as potassium, and falls off with prolonged heating; for metallic salts it consists of ions of the metal composing the salt. Some metals emit electrons much more copiously than others; a notable example is **thorium,** an adsorbed film of which on tungsten gives very copious electron emission at high temperatures. (See also **Richardson-Dushman equation; Schottky effect;** and **space charge limitation of currents.**)

THERMIONIC TUBE. See **tube, thermionic.**

THERMISTOR. A resistance element made of a **semiconducting material** which exhibits a high negative temperature coefficient of **resistivity.**

THERMISTOR, BEAD. A thermistor consisting of a small bead of semiconducting ma-



Bead thermistor (By permission from "Microwave Theory and Techniques" by Reich et al., Copyright 1953, D Van Nostrand Co., Inc.)

terial placed between two wire leads. It is used for microwave power measurement, temperature measurement, and as a protective device.

THERMOCOUPLE. A device consisting of two metals, one of whose junctions is kept at a fixed temperature. The **thermoelectric** electromotive force generated in the circuit is measured to give the temperature of the other junction, making a convenient and simple **thermometer.** (For detailed discussion, see **thermel.**)

THERMOCOUPLE METER. A combination of the **thermocouple** and sensitive millivoltmeter which measures the **electromotive force** developed by the thermocouple as the result of its heating by the current passed through a resistance element in thermal contact with it. Thermocouple meters read **root-mean-square** values of alternating currents at frequencies extending as high as radio frequencies.

THERMOCOUPLE VOLTMETER. See **voltmeter, thermocouple.**

THERMODYNAMIC EQUATIONS OF STATE. Any equation derived by consideration of reversible energy changes, which gives a relationship between pressure, volume and temperature for a state of matter. Specifically, the two exact equations

$$p = T\left(\frac{\partial p}{\partial T}\right)_V - \left(\frac{\partial U}{\partial V}\right)_T$$

$$V = T\left(\frac{\partial V}{\partial T}\right)_p + \left(\frac{\partial H}{\partial p}\right)_T$$

where p is the pressure, V, the volume, U, the **internal energy,** H, the **enthalpy,** and T, the absolute temperature. They are useful in evaluating **thermodynamic functions** when the **equation of state** is known.

THERMODYNAMIC POTENTIAL. (1) For a substance in any given state, the energy which is required to bring unit mass of the substance to the state in question from some arbitrarily-defined, initial state. (2) The Gibbs free energy G (see **free energy (1)**), which is defined by the equation

$$G = U - TS + pV$$

where U is the internal energy, T is the absolute temperature, S is the entropy, p is the pressure and V is the volume. (3) Any other additive quantity which is a function of state, such as the **entropy, enthalpy,** or the Helmholtz **free energy,** may also be spoken of as a thermodynamic potential.

THERMODYNAMIC PROBABILITY. The number of *a priori* equally probable states of a statistical assembly, usually denoted by Ω. It is a measure of the disorder of the assembly, and is connected with the entropy S by the relation

$$S = k \ln \Omega,$$

where k is the **Boltzmann constant.**

THERMODYNAMIC QUANTITIES. Macroscopic quantities which affect the internal state of a system, determining its **internal energy.**

THERMODYNAMIC SYSTEM. A system whose behavior may be described by **thermodynamic quantities.**

THERMODYNAMIC TEMPERATURE SCALE. See discussion of **thermometry.**

THERMODYNAMICS. This branch of physics had its origin in the classical discoveries of Rumford, Davy, Joule, and others early in the nineteenth century, which identified **heat** as a form of **energy.** Gradually the mechanism of heat and the statistics of molecular motion were revealed by the researches of such men as Maxwell, Kelvin, Clausius, and Boltzmann, until now, with the added assistance of the **quantum theory,** we discuss the dynamics of **molecules** almost as confidently as that of visible bodies.

The variables commonly chosen in thermodynamic reasoning are temperature, entropy, pressure, and volume, and in terms of these we write the **characteristic equations** of the substances, such as air, steam, etc., used in engines. The purely dynamic aspects are especially concerned with volume and pressure, and thermodynamic diagrams are often drawn with these as coordinates. For example, if a gas expands and its pressure diminishes, this change may be represented by the curve AB and the corresponding work by the area $AB\beta\alpha$ (Fig. 1); while if, as in an engine, the change is a cyclic one, the net work derived from each cycle on one side of the pis-

ton is represented by the area W enclosed by the curve (Fig. 2). A steam engine indicator, for example, automatically draws such

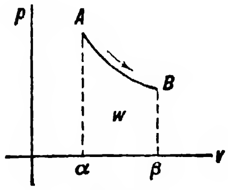


Fig. 1

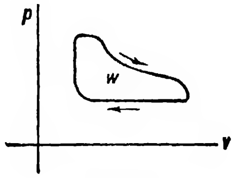


Fig. 2

Representation of work during a unidirectional or a cyclic change in volume and pressure

a curve at each stroke of the engine, the efficiency of whose performance can thus be deduced. (See **thermodynamics, first law of, thermodynamics, second law of, thermodynamics, third law of, thermodynamics, zeroth law of, Carnot cycle, Rankine cycle, entropy, Joule-Thomson effect, reversible processes,** etc.)

THERMODYNAMICS, BASIC EQUATIONS. The four following equations were called by Gibbs the fundamental equations of thermodynamics:

$$dU = TdS - pdV + \sum_i \mu_i dn_i$$

$$dA = -Sdt - pdV - \sum_i \mu_i dn_i$$

$$dH = TdS + Vdp + \sum_i \mu_i dn_i$$

$$dG = -Sdt + Vdp + \sum_i \mu_i dn_i$$

where T is the absolute temperature, S, the **entropy,** p, the pressure, V, the volume and μ_i, the **chemical potential** of the species i, of which n_i moles are present in the phase. $\sum_i$ denotes summation over the species in the phase, and U **(internal energy),** A **(free energy (2)),** H **(enthalpy)** and G **(free energy (1))** are thermodynamic potentials. By use of these equations, all the thermodynamic functions can be expressed in terms of the chosen thermodynamic potential.

THERMODYNAMICS, FIRST LAW OF. One of the many forms of statement of this law is that energy cannot be created or destroyed, but can only be converted from one form to an equivalent quantity of another form. The discovery of the equivalence of mass and energy, based on the relativity theory, and its application in the conversion of mass into energy in nuclear reactions, has become the basis for a broader generalization, combining the first law of thermodynamics with the law of conservation of matter, in the statement that the total mass and energy of a system, whether expressed in terms of equivalent total mass or equivalent total energy, is constant.

THERMODYNAMICS, SECOND LAW OF. One of the many forms of statement of this law is that heat cannot pass from a colder to a hotter body without the intervention of some external force, medium, or agency. It follows from this law that all natural or isolated processes which occur spontaneously are irreversible.

THERMODYNAMICS, THIRD LAW OF. Every substance has a finite positive **entropy** which may become zero at a temperature of absolute zero, as it does in the case of crystalline substances. (Methods of quantum statistics, however, show that entropies at absolute zero, while small, are not necessarily zero, there being, for example, a finite entropy due to nuclear spin.)

THERMODYNAMICS, ZEROTH LAW OF. When two bodies are in thermal equilibrium, no heat flows from one to the other and both are at the same temperature.

THERMOELASTIC COEFFICIENT. The **modulus of elasticity,** which is defined for a three-dimensional system (e.g., a gas) by one of the following expressions:

$$-v\left(\frac{\partial p}{\partial v}\right)_T \text{ (isothermal bulk modulus)}$$

$$-v\left(\frac{\partial p}{\partial v}\right)_S \text{ (adiabatic bulk modulus)}$$

where v is the volume, p, the pressure, T, the absolute temperature, S, the entropy. These quantities are the reciprocals, respectively, of the **isothermal** and **adiabatic compressibilities.**

THERMOELASTIC RELAXATION LOSS. See **thermal diffusion relaxation.**

THERMOELECTRIC PHENOMENA. The effect associated with the change of the **con-**

tact potential of two metals with temperature. Hence, a current may be produced by keeping one junction at a different temperature from the other (**Peltier effect**). There is also an effect associated with the electromotive force generated in a wire which is in a thermal gradient (Thomson effect). The thermoelectromotive force of a thermocouple appears to be a combination of a "Peltier electromotive force" at the junction and the Kelvin or "Thomson electromotive forces" in the two strips. If several metals are joined to form a circuit of non-uniform temperature, the resultant thermoelectromotive force is the algebraic sum of the several Peltier and Thomson electromotive forces, and gives rise to a thermoelectric current, such as that utilized in any thermel. Kelvin discovered that if a weak current is sent through a wire which is heated at one point, the current causes a flow of heat, sometimes one way and sometimes the other, depending upon the metal

THERMOELECTRIC POWER. The thermoelectric force per degree, dE_{AB}/dT, where E_{AB} is the emf generated at the junction of metals A and B at temperature T From the definition

$$S_A = \frac{dE_A}{dT} = \int_0^T \frac{\sigma_A dT}{T}$$

the absolute thermoelectric power is obtained from the values of the **Thomson coefficient,** σ_A, at all temperatures, measured at low temperatures against a superconductor whose Thomson effect vanishes The **Peltier coefficient** of two metals is then given by

$$\pi_{AB} = -T(S_B - S_A).$$

THERMOELECTROMOTIVE FORCE. See **thermoelectric phenomena.**

THERMOELECTRON. A negative **thermion.**

THERMOGRAPH. An instrument used to make a continuous record of temperature.

THERMOMETER. An instrument used to measure the intensity of the heat in a body, i.e., its temperature, usually constructed so that the expansion of matter caused by heat furnishes the measure of the temperature. Instruments for measuring high temperatures are termed **pyrometers,** and are based upon measurements of the amount of radiation emitted by the hot body, or by measurement of the amount of radiation of a particular frequency or narrow band of frequencies, or by measurement of the change in resistance of a standard length of wire, or by the use of a thermocouple. (See **thermel.**)

THERMOMETER, BOURDON. A flat hollow tube filled with an organic liquid. As the temperature of the liquid increases, its expansion causes the tube to straighten.

THERMOMETER, CONSTANT-PRESSURE. An instrument for measuring temperatures based on the expansion of a gas with increasing temperature, the pressure remaining constant. The gas is contained in a bulb connected by a tube to a suitable device for keeping the pressure constant and measuring the change in volume on expansion (e.g., a mercury manometer with additional reservoir of mercury) Various practical corrections must be made, notably for the "dead space" containing gas not at the temperature to be measured, and the instrument must be calibrated at the standard fixed points. Gases are used which are as near as possible to being ideal When corrected for departure from ideality, the "ideal gas scale" temperature thus measured can be shown to be identical with the absolute thermodynamic scale temperature (discussed under **thermometry**)

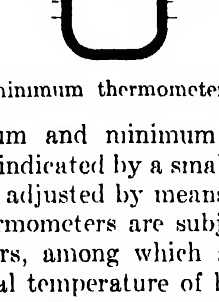
THERMOMETER, CONSTANT VOLUME. An instrument for measuring temperatures based on the increase in pressure of a gas with temperature, the volume remaining constant The gas is contained in a bulb connected by a tube to a suitable device for keeping the volume constant, and measuring the change in pressure Corrections must be made similar to those for the constant pressure thermometer (preceding article), and the instrument then also gives temperatures identical with the absolute thermodynamic scale temperatures (discussed under **thermometry**).

THERMOMETER, HYDROGEN. A gas thermometer using hydrogen. (See **thermometry.**)

THERMOMETER, LIQUID-EXPANSION. This familiar instrument for measuring **temperature,** developed by Fahrenheit and others, makes use of the relative expansion of a liquid and its transparent container. The use of mercury as a thermometric substance

is recommended by its high boiling point (+357°C) and low freezing point (−39°C), and by the constancy of its expansion coefficient. Alcohol is often substituted, because of its much lower freezing point (−114°C), and because its expansion coefficient is more than six times that of mercury; it is also lighter and cheaper. Its boiling point, however, is so low (78°C) that it cannot be used for high temperatures; and it must be stained to be easily visible. In some mercury thermometers an inert gas is introduced above the mercury, the pressure of which, as the mercury expands, raises the boiling point of the mercury and hence increases the range. The Beckmann mercury thermometer has a very large bulb and a very fine bore with a storage reservoir for mercury at the top. It is used only for differential temperature measurements, with a range of only a few degrees, and is graduated to hundredths of a degree.

Some thermometers are designed to indicate the maximum or the minimum temperature attained during a given period. The best maximum thermometers employ mercury, with a constriction just above the bulb at which the mercury thread separates when the temperature starts to fall, leaving the top of the column to mark the highest temperature. Minimum thermometers employ alcohol, with a light, solid index or marker just inside the free surface. As the temperature falls, this marker is pushed down by the surface tension, and remains at the lowest point attained In a thermometer devised by Sixe,



A maximum-minimum thermometer (Sixe's form)

both maximum and minimum temperatures are similarly indicated by a small iron marker, which can be adjusted by means of a magnet.

Liquid thermometers are subject to certain inherent errors, among which are those due to the unequal temperature of bulb and stem and to the imperfect recovery of the volume of the bulb after heating. The latter effect may accumulate over a long period, requiring recalibration from time to time, especially if the instrument is used over wide ranges of temperature.

THERMOMETER, MAXIMUM. A thermometer which indicates the maximum temperature reached. The simplest type is a fluid-in-glass thermometer so constructed that a small segment of the fluid "breaks-off" when the fluid begins to fall.

THERMOMETER, MINIMUM. A thermometer which indicates the minimum temperature reached. The simplest type is a fluid-in-glass thermometer containing a small index which moves downward with the surface of the fluid, but does not move upward by action of the fluid alone.

THERMOMETER, SOLID EXPANSION. Many devices have employed the expansion of solid bodies as an indicator of temperature change Wedgwood, a celebrated 18th-century potter, used small blocks of burned clay to estimate, by their expansion, the temperature of his kilns. Because of the low expansion coefficient, any such direct application of solids is necessarily very insensitive; on the other hand the requirement of durability favors their use in certain cases. One rather crude arrangement, sometimes used, is a long wire passing over pulleys, its length being sufficient to insure a measurable expansion

More commonly, use is made of the warping produced by the differential expansion of two solid strips fastened together. The Breguet spiral is composed of two spiral strips, like watch springs, made of different metals and securely welded together throughout their length. A change in temperature causes the combination to coil or uncoil, a motion which, communicated through gears to a pointer-shaft, serves to give temperature readings on a dial.

THERMOMETER, WEIGHT. Instrument for measuring the apparent coefficient of expansion of a liquid relative to a containing vessel by determination of the amount of liquid expelled from the vessel on heating through a measured temperature interval.

THERMOMETRIC COEFFICIENT. One of the following two coefficients: (1) Coeffi-

cient of change of pressure at constant volume defined as

$$\frac{1}{p}\left(\frac{\partial p}{\partial T}\right)_v.$$

(2) Coefficient of expansion at constant pressure, defined as

$$\frac{1}{v}\left(\frac{\partial v}{\partial T}\right)_p.$$

In these expressions, p is the pressure, T, the absolute temperature, v, the volume.

THERMOMETRY. The measurement of **temperature** and of changes in temperature has been based upon many different heat effects Among those which have been extensively developed are: (1) the expansion of solids, liquids, and gases, illustrated by **thermometer, solid expansion; thermometer, liquid expansion;** and the constant pressure **gas thermometer;** (2) the change of pressure in a gas kept at constant volume (constant volume gas thermometer), or of the saturated vapor pressure of a liquid (see **vapors**); (3) the change in resistivity of metals (metallic **resistance thermometer**); (4) the Seebeck thermoelectric effect (**thermel**); (5) the brightness of very hot bodies (**optical pyrometer**); and (6) the character of the **thermal radiation** from the heated body (**radiation pyrometer**)

With so many temperature indices, it is necessary to have a standard of temperature measure. For various reasons, it was once found desirable to fix upon gas pressure at constant volume as the practical standard measure of temperature. That is, equal changes of temperature were defined as those corresponding to equal changes of pressure in a selected gas (hydrogen) kept at constant volume. The constant volume hydrogen thermometer thus became the reference instrument for the calibration of other types. In 1927, however, the United States, Great Britain, and Germany proposed, and thirty-one nations represented at the Seventh General Conference of Weights and Measures unanimously adopted, what is now called the international temperature scale. From −190° to +660°C, the measure of temperature is based upon the indications of a standard platinum resistance thermometer, specified and used in accordance with certain formulas. From +660°C to the melting point of gold a platinum-platinrhodium thermel is the reference instrument; and above the gold point, the optical pyrometer is used as standard. The basic fixed points of this scale are the boiling point of **oxygen** (−182.97°C), the freezing and the boiling points of water, the boiling point of **sulfur** (+444 60°C), the melting point of **silver** (+960.5°C), and the melting point of gold (+1063°C).

Kelvin was long ago impressed with the dependence of such thermometric methods upon characteristic properties of certain arbitrarily chosen substances. Even constant-volume gas thermometers, using different gases, do not quite agree. Kelvin therefore proposed an ideal absolute temperature scale on which changes of temperature, whatever the substance concerned, are strictly proportional to the quantities of heat converted into mechanical work during **Carnot cycles** bounded by the respective temperatures and by the same two adiabatic **entropy** limits A constant-volume gas pressure thermometer using a gas obeying the **ideal gas law** would perform in exact agreement with this standard The subsequent researches of Joule and Kelvin on the **Joule-Thomson effect** enabled them to calculate the corrections necessary to convert the hydrogen constant volume standard into this "thermodynamic scale" (more properly, this thermodynamic standard of temperature measure) proposed by Kelvin, which is now used as the basis of the international scale above mentioned.

THERMOMOLECULAR PRESSURE. If two vessels containing a gas are separated by an insulating partition, in which there is an orifice whose linear dimensions are small compared with the **mean free path** of the gas molecules, it is found that a temperature difference between the two vessels is accompanied by a difference in pressure. This is known as the *thermomolecular pressure difference*, and it can be shown from elementary kinetic theory that

$$\frac{p_1}{p_2} = \sqrt{\frac{T_1}{T_2}}$$

where p_1, T_1 are the pressure and temperature in one vessel, and p_2, T_2 the pressure and temperature in the other. This effect also takes place when a tube, along which there is a temperature gradient, contains a gas at such

a pressure that the mean free path of the molecules is comparable with the diameter of the tube. In this case, however, the simple relationship does not apply. The effect is especially important in low-temperature gas thermometry.

THERMONUCLEAR REACTION. A **nuclear reaction** in which the energy necessary for the reaction is provided by colliding particles that have kinetic energy by virtue of their thermal agitation. Such reactions occur at appreciable rates only for temperatures of millions of degrees and higher, the rate increasing enormously with temperature. The energy of most stars is believed to be derived from exothermic thermonuclear reactions. (See **carbon cycle**; **proton-proton chain.**)

THERMOPHONE. An electroacoustic transducer (see **transducer, electroacoustic**) in which sound waves of calculable magnitude result from the expansion and contraction of the air adjacent to a conductor whose temperature varies in response to a current input. When used for the calibration of pressure microphones, a thermophone is generally used in a cavity the dimensions of which are small compared to a wavelength.

THERMOPHOSPHORESCENCE (THERMOLUMINESCENCE). **Phosphorescence** developed by heating after exposure to some exciting agency.

THERMOPILE. A device for measuring temperature (difference), consisting of a closed electric circuit made of two different metals and an electric meter. It consists of a number of **thermocouples** in series, all junctions of type A-B being thermally connected, as are all of type B-A. When the two sets of junctions between the metals are at different temperatures, an electromotive force is developed. Radiation, incident upon and absorbed by one set of junctions, is measured by the emf developed by the resulting rise in temperature of that junction. Also called the **thermel.**

THERMOSTAT. An apparatus arranged so that it may be adjusted to maintain and keep constant any practicable temperature. A system enclosed in a thermostat is thus kept at a definite constant temperature. This is usually accomplished by actuating controls which turn the heating mechanism on when an upper temperature limit is reached and which turn it off when a lower temperature limit is reached.

THETA. (1) Temperature absolute or Kelvin (Θ, but T is more commonly used), temperature, Debye characteristic (Θ), temperature, ordinary (θ or t). (2) Angle, plane (θ), angle, glancing (θ), angle of contact (θ), angle of optical rotation (θ), angular displacement (θ).

THETA FUNCTION. An infinite **series** of the form

$$\theta(z,q) = 1 + 2 \sum_{n=1}^{\infty} q^{n^2} \cos 2nz,$$

which is related to **elliptic functions** and which is especially useful in making numerical calculations with such functions.

THETA POLARIZATION. See **polarization, theta (θ).**

THEVENIN THEOREM. The current in any terminating impedance Z_T connected to any network is the same as if Z_T were connected to a generator whose voltage is the open circuit voltage of the network, and whose internal impedance Z_R is the impedance looking back from the terminals of Z_T, with all generators replaced by impedances equal to the internal impedance of these generators.

THIN-LENS RELATIONSHIPS. Formulas relating image distance, object distance, focal length, index of refraction, curvature of surfaces, etc., of a lens which is sufficiently thin that, for the purpose of the calculation, the thickness may be neglected.

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = (n-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

is a typical thin-lens formula.

THIN PRISM FORMULA. See **prism, thin, formula.**

THIRD ORDER THEORY. Lens computations in which the first two terms only of the series expansion of

$$\sin\theta = \theta - \frac{\theta^3}{3!} + \frac{\theta^5}{5!} - \cdots$$

are used. Third order theory gives the five geometrical **aberrations** of Seidel.

THIXOTROPIC FLUID. See **fluid, thixotropic.**

THIXOTROPY. The property exhibited by certain **gels** of liquefying when subjected to the action of vibratory forces, such as **ultrasonic waves** or even simple shaking, and then setting again on standing. Gels of this type may be formed by the addition of small quantities of electrolyte to concentrated sols of certain metallic oxides, such as ferric oxide, aluminum trioxide, zirconium dioxide, etc., and also other sols, including those of the bentonite clays, and certain gelatin preparations.

THOLLOW PRISM. See **prism, Thollow.**

THOMAS-FERMI DIFFERENTIAL EQUATION. An equation which occurs in studying the electron distribution in an atom

$$y''\sqrt{x} = y^{3/2}.$$

Although a special solution can be given as $x^3y = 144$, it is required for physical reasons that $y(0) = 1$, $y(\infty) = 0$. Solutions satisfying these boundary conditions must be found by **numerical** or **graphical methods.**

THOMAS-FERMI MODEL. A method for the calculation of atomic energy levels based on a statistical treatment of the assembly of electrons. (See **Thomas-Fermi differential equation.**)

THOMAS METER. An instrument for measuring the rate of flow of a gas in terms of the increase in temperature of the gas produced by a known quantity of heat.

THOMAS PRECESSION. If in the **Lorentz frame** instantaneously at rest relative to an accelerated system there is a vector in that system which appears to be constant, then relative to an observer for whom the system has velocity **v**, acceleration $\dot{\mathbf{v}}$ the vector will appear to precess with the angular velocity

$$\boldsymbol{\omega} = \frac{1}{2c^2}\dot{\mathbf{v}} \times \mathbf{v}.$$

This is the kinematical basis for **spin-orbit coupling** in atoms.

THOMAS-REICHE-KUHN, *f*-SUM RULE OF. See ***f*-sum rule of Thomas-Reiche-Kuhn.**

THOMSON-BERTHELOT PRINCIPLE. The assumption that the heat evolved in a chemical reaction is a direct measure of chemical affinity, and that every chemical change taking place without the intervention of external energy tends to the production of that system which evolves most heat. This assumption is in general wrong except for certain special cases, since according to the principle, no spontaneous reactions could take place which absorb heat, and all reactions should proceed in one direction only, i.e., reversible reactions should be impossible. The correct criterion for a chemical reaction is the change in **free energy,** and the principle is thus true or approximately true when this is equal or nearly equal to the heat of reaction, e.g., in constant-volume reactions, in reactions between liquids and solids, and at low temperatures.

THOMSON COEFFICIENT. The coefficients σ_A and σ_B associated with metals A and B and related to the **thermoelectric emf,** E_{AB}, generated at temperature T by a thermojunction in accordance with the second Thomson relation

$$\sigma_A - \sigma_B = Td^2E_{AB}/dT^2.$$

(See also **thermoelectric phenomena** and **Thomson effect.**)

THOMSON EFFECT. One of the thermoelectric effects (see **thermoelectric phenomena**). When an electric current J passes between two points of a homogeneous wire whose temperature difference is ΔT, an amount of heat $\sigma J\Delta T$ is emitted or absorbed in addition to the **Joule heat.** σ is the **Thomson coefficient.**

THOMSON ISOTHERM. An S-shaped **isotherm** showing the continuous transition from the gaseous to the liquid state.

THOMSON, LAW OF (LAW OF HELMHOLTZ, THOMSON'S RULE). In an electric cell the **heat of reaction** is a direct measure of the **electromotive force,** i.e., the chemical energy is simply converted into electrical energy. This is only approximately true, for part of the energy of an electric cell appears as heat, either absorbed or evolved as the case

may be. (See **Gibbs-Helmholtz equation for a reversible cell.**)

THOMSON PARABOLA METHOD. The method of investigating the **charge-to-mass ratio** of positive ions in which the ions are acted upon by electric and magnetic fields applied in the same direction normal to the path of the ions. It can be shown that ions of a given **charge-to-mass ratio** but different velocities will be deflected so as to form a parabola.

THOMSON PRINCIPLE. The hypothesis that, if thermodynamically reversible and irreversible processes take place simultaneously in a system, the laws of thermodynamics may be applied to the reversible process while ignoring for this purpose the creation of entropy due to the irreversible process. Applied originally by Thomson to the case of thermoelectric effects. Also used in the treatment of electrochemical cells, thermal diffusion, etc.

THOMSON RELATIONS. Equations governing **thermoelectricity**, deduced originally by thermodynamics (see **Thomson coefficient, Peltier coefficient**). An important result is the relation between the Thomson coefficients σ_A, σ_B, of two metals, and their Peltier coefficient π_{AB}.

$$\frac{d}{dT}\left(\frac{\pi_{AB}}{T}\right) = \frac{\sigma_A - \sigma_B}{T}.$$

THOMSON SCATTERING. See **scattering, Thomson.**

THORIATED EMITTER. A thermionic emitter (see **thermionic phenomena,** also **emission, thermionic**) consisting of a directly-heated tungsten filament to which has been added a small quantity of thorium oxide. During the evacuation process, some of the thorium oxide is converted to metallic thorium which covers the cathode area in a thin coat. The resultant **work function** is considerably less than that for a pure tungsten filament.

THORIUM. Metallic radioactive element. Symbol Th. Atomic number 90.

THORIUM SERIES. The **radioactive series** starting with thorium of mass number 232.

THORON. Thorium emanation, an isotope of **radon.**

THREE-BODY PROBLEM. If we assume that three or more objects exist in the universe, each of them attracting every other in accordance with the law of **gravitation,** the problem of predicting subsequent positions and motions is commonly referred to as the three-body problem, or the n-body problem.

The **two-body problem** has been completely solved and the full solution may be expressed in comparatively few words and symbols. However, if we add one or more other bodies the solution becomes one of exceeding complexity and has never been accomplished in any form which is at all suitable for computational purposes. In fact, only one complete solution has ever been made, in spite of the labors of practically all of the great mathematicians of past centuries.

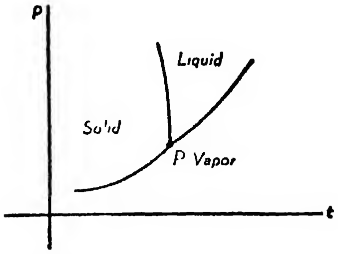
Even though no general solution of the problem is available, nevertheless, there are several practical computational methods for determining the positions of planets and other members of the solar system, taking into account the gravitational attraction of all effective members. Such solutions are all made by successive approximations and various methods of computing **perturbations,** rather than by the application of any general solution.

A number of particular solutions of the three-body problem have been made by mathematicians, notable among them being the solution by Lagrange. He showed that it is possible for an asteroid to be stable in a position such that it is equidistant from both the sun and Jupiter. In this case the three objects would be on the vertices of an equilateral triangle and the asteroid **orbit** would have the same period as that of Jupiter. This case is illustrated in nature by the members of the so-called Trojan group.

THREE-INDEX SYMBOLS. See **Christoffel brackets.**

THREE-PHASE EQUILIBRIUM. For every pure, chemically stable substance there is a certain temperature and pressure at which it can exist in all three states or phases, solid, liquid, and vapor, each phase being in equilibrium with each of the others. At higher temperatures and pressures than those at this so-called "triple point," the liquid and vapor states may attain equilibrium; solid-vapor equilibrium (see **sublimation**) is possible at lower temperatures and pressures; while solid-

liquid equilibrium can be obtained at higher pressures and at lower or higher temperatures according as the substance contracts or expands upon melting (see **fusion**). These three equilibria may be represented by three temperature-pressure graphs which converge at the triple point. The figure illustrates the case of water, which contracts on melting, and



Triple point (P) on temperature-pressure diagram for water

for which the triple point is at +0.0072°C and 4.6 mm of mercury. (See also **phase rule.**)

THREE-WIRE SYSTEM. Many of the domestic and small commercial electric power loads are supplied by a dual-voltage, three-wire system, the voltage between two of the wires being about 220 volts while that between the other two wire combinations is approximately 110 volts. As usually shown schematically the neutral wire (the one common to the two 110-volt combinations) is placed in the center, giving 110 volts between the neutral and either outside wire while the outside wires have 220 volts between them. In applying the load to this type system an attempt is made to keep it balanced on either side of neutral. For a perfectly balanced load no current flows in the center wire, while for an unbalanced load only the unbalance current (the difference between the currents in the two 110-volt loads) is carried by the neutral wire. Thus there is a reduction in power loss and voltage drop in the line, giving a better, more efficient service. (See **balance coil.**)

THRESHOLD, ABSOLUTE LUMINANCE. The minimum **luminance** which can be discriminated by the fully dark-adapted eye.

THRESHOLD, ABSOLUTE PURITY. The minimum **purity** perceptible in contrast with white, by the light-adapted eye. The absolute purity threshold is a function of wavelength.

THRESHOLD AUDIOGRAM. See **audiogram.**

THRESHOLD, COLOR. Any measure, either absolute or differential, of the degree of color discrimination. (See **discrimination, color.**)

THRESHOLD CURRENT. The current at which a **gas discharge** changes from a non-self-sustained to a self-sustained discharge.

THRESHOLD, DIFFERENTIAL COLOR. The amount of difference between two colors which is necessary for perceptibility in a stipulated percentage of independent trials.

THRESHOLD ENERGY; THRESHOLD. (1) The energy limit for an incident particle or photon below which a particular endothermic reaction will not occur. It is specified with reference to the **laboratory system of coordinates.** For a reaction between two nonrelativistic particles, the relation of the threshold energy to the Q-value is:

$$\text{Threshold energy} = Q\left(\frac{m_i}{m_t} + 1\right)$$

where m_i is the mass of the incident particle; m_t, of the target nucleus, and the Q-value is the **nuclear disintegration energy.** (2) The energy limit for an incident particle or photon below which a particular **nuclear reaction** cannot be observed; sometimes called the practical threshold energy. It is frequently determined by Coulomb barrier effects. Exothermic as well as endothermic reactions may have threshold energies.

THRESHOLD FREQUENCY. The minimum frequency of radiation for a given surface for the emission of electrons. (See **photoelectric threshold.**)

THRESHOLD OF AUDIBILITY. See **audibility, threshold of.**

THRESHOLD OF DETECTABILITY. See **audibility, threshold of.**

THRESHOLD OF FEELING (OR DISCOMFORT, TICKLE, OR PAIN). For a specified signal, the minimum effective sound pressure (see discussion under **sound pressure, effective**) of that signal which, in a specified fraction of the trials, will stimulate the ear to a point at which there is the sensation of feeling (or discomfort, tickle, or pain). Char-

acteristics of the signal and the measuring technique should be specified in every case. This threshold is customarily expressed in **decibels** relative to 0.0002 microbar or 1 **microbar.**

THRESHOLD PRESSURE. See discussion of **audibility, threshold of.**

THRESHOLD, RELATIVE LUMINANCE. The ratio of the differential luminance threshold (see **threshold, absolute luminance**) of two colors to the **luminance** of the less luminous of the two. This is called the **Fechner fraction.** (See also **Mackenzie equation.**)

THRESHOLD VALUE. The minimum input which produces a corrective action in the power element of an **automatic controller.**

THRESHOLD VOLTAGE FOR GEIGER COUNTING ACTION. The lowest voltage at which all **pulses** produced in the **counter** by any **ionizing event** are of the same size, regardless of the size of the **primary ionizing event.**

THRESHOLD WAVELENGTH. The maximum wavelength of radiation for a given surface for the emission of electrons. (See **photoelectric threshold.**)

THROAT MICROPHONE. See **microphone, throat.**

THROW-OUT SPIRAL. An **eccentric spiral.**

THRUST. The reaction force to the gaseous discharge from a rocket or jet. It is equal to μV, where μ is the mass discharge per unit time, and V is the velocity of discharge. (See **Newton Laws of Motion (3).**)

THYRATRON. A hot-cathode **gas tube** in which one or more control electrodes initiate, but do not limit, the anode current, except under certain operating conditions.

THYRATRON, SHIELD-GRID. A four-element **thyratron** employing a massive shield grid, usually operated at cathode potential, to almost completely shield the control grid from the cathode, anode, tube walls, and light in order to reduce the current drawn by the **control grid** before ignition.

THYRITE. Trade name for a silicon carbide material with a large negative voltage coefficient of **resistivity.** It also has an appreciable, negative temperature coefficient of resistivity. A form of **varistor.**

THULIUM. Rare earth metallic element. Symbol Tm. Atomic number 69.

THUNDER. A sound wave set up by an electrical discharge in the atmosphere, all along the column of air in which the discharge has occurred. If the discharge occurs close at hand, there is one sharp burst or "explosion," but if the discharge occurs some distance away then portions of the sound wave reach an observer over a period of time. Echoes of thunder also occur when the sound wave or parts of it are reflected from objects projecting from the earth, such as hills and buildings.

THUNDERSTORMS. Cumulonimbus clouds accompanied by lightning and thunder. Normally thunderstorms are accompanied by torrential rain for brief moments during the passage of the storm, but occasionally no precipitation reaches the ground. Often they cause hail and gusty surface winds of considerable velocity. Sometimes they are attended by tornadoes which cause great damage. Vertical velocities inside thunderstorms are extremely erratic and as high as 120 mph.

TICKLER. The coil used to couple plate-circuit energy into the grid circuit of some forms of **regenerative detectors** and **oscillators.**

TIDES, DYNAMICAL THEORY OF. The theory of tidal motion in the sea that considers the effects on the rise and fall of the necessity for the water to flow in seas of finite depth bounded by land masses. It provides explanations of the differences between the observed tides and the tides computed on the equilibrium theory.

TIDES, EQUILIBRIUM THEORY OF. A theory which assumes the sea surface to be always coincident with a surface of constant gravitational potential due to the attractions of the earth and moon. Its predictions are seriously in error near land masses or in enclosed seas where dynamical effects lead in general to much larger tides.

TIE LINE. On an **equilibrium diagram,** a line joining two points which represent the compositions of systems in equilibrium

TIGHT BINDING APPROXIMATION. One of two alternative approaches to the problem of calculating the energy of an electron in a solid It is assumed that the electron is effectively in an **atomic orbital** centered on a particular atom of the lattice, with a small perturbation allowing it to jump to neighboring sites The assumed wave function is thus a **Bloch function** in which the periodic function is a pure **atomic wave function.** This approximation works well for narrow deep-lying **bands,** but must be augmented with the **free-electron** type of approximation for **conduction electrons.**

TIMBRE (MUSICAL QUALITY). That attribute of auditory sensation in terms of which a listener can judge that two sounds similarly presented and having the same loudness and pitch are dissimilar Timbre depends primarily upon the spectrum of the stimulus, but it also depends upon the wave form, the **sound pressure,** and the frequency location of the spectrum of the stimulus

TIME. The mode of grouping sense impressions by the order in which events are observed Abstract time, as used in mechanics and physics generally, is a parameter serving as the fundamental independent variable in terms of which the relative behavior of all physical systems may be compared As a parameter it may take on all the succession of values of the real number continuum It may also be thought of as the measure of duration of an event, though this is more properly referred to as a time interval (See also **relativity theory, special.**)

TIME AVERAGE. The time average of any time-dependent physical quantity over a given time interval is the time integral of the quantity taken over the interval, divided by the magnitude of the interval

TIME CONSTANT. (1) All **photon** detectors require a certain time to respond to a radiation pulse and continue to respond for a small time after the radiation is cut off The time involved may vary from a fraction of a microsecond to several seconds, according to the nature of the detector. A common definition (1955) of time constant T is given by $T = 1/2\pi f$ where f is the frequency of chopping of the radiation by a sine wave which causes the root-mean-square signal to decrease by 3 **decibels** from the signal for very slow chopping (2) It may also be defined as the time required for the voltage or current in a circuit to rise to 63% of its final value, or fall to 37% of its initial value, as a result of step input

TIME CONSTANT CIRCUIT. See **circuit, time constant.**

TIME DELAY. The time required by a specific voltage or current to travel through a circuit

TIME DEMODULATION. The process by which information is obtained from a time-modulated wave about the signal imparted to the wave in **time modulation.**

TIME DILATION. See **slowing of clocks.**

TIME DIVISION. The process of propagating a plurality of information-bearing signals over a common medium, allocating a different time interval for the transmission of each signal (See **time-division multiplex**.)

TIME-DIVISION MULTIPLEX. The process or device in which each **modulating wave** modulates a separate **pulse subcarrier,** the pulse subcarriers being spaced in time so that no two pulses occupy the same time interval Time division permits the transmission of two or more signals over a common path by using different time intervals for the transmission of the intelligence of each message signal

TIME DISCRIMINATOR. A circuit which indicates the time equality of two events, or the sense and approximate magnitude of the inequality

TIME GATE. A **transducer** which gives output only during chosen time intervals

TIME-LIKE VECTOR. A **four vector** A_μ in **Minkowski space** such that $A_\mu A_\mu < 0$

TIME MODULATION. Modulation in which the time of appearance of a definite portion of a **waveform,** measured with respect to a reference time, is varied in accordance with a signal.

TIME PATTERN. A picture-tube presentation of horizontal and vertical lines or dot rows generated by two stable frequency

sources operating at multiples of the line and field frequencies.

TIME REVERSAL. The operation of replacing the t by $-t$ in the equations of motion of a dynamical system. Of particular interest in **quantum mechanics** where the operation corresponds to a unitary transformation on the wave-function. From this some general properties of the **scattering matrix** (e.g., the reciprocity theorem) may be deduced for a system for which time-reversal is possible without changing the **Hamiltonian** fundamentally.

TIME-SELECTION TRANSDUCER. A gating or **coincidence circuit.**

TIME, STANDARD. With the adoption of mean solar **time** and the improvement in the manufacture of time pieces, each locality set its clocks to indicate its own local mean time. As railway systems developed, an intolerable confusion resulted from so many different local times being used along the lines. The first step toward standard time was the introduction of so-called "railway time" which was the local civil time of some important station on a particular railroad. As interstate and international communication expanded, particularly after the invention of the telephone and telegraph, it became apparent that a universal standardization of time must be adopted.

The modern plan developed from a suggestion made by Sandford Fleming in 1878 and is now used by the armed services and international sea and air transport systems. This Zone Time is described in a separate article but has never been adopted for civilian life, although it is approximated to in the Standard Time system which is in general use. A few of the smaller nations still use the local civil times of their individual capitals as standard everywhere within their borders. The larger nations employ a system on which the earth is divided into standard time zones. Each zone is 15° of longitude, or one hour of time, in width, with the center of each zone an integral number of hours east or west of Greenwich, England.

In Canada and the United States five standard time zones are employed. These are known as Atlantic (Maritime), Eastern, Central, Mountain, and Pacific, and the centers of each are 4, 5, 6, 7, and 8 hours west of Greenwich, respectively. The boundaries of each zone are not set along meridians of longitude, but are determined by national, state, municipal, or commercial convenience. In regions close to the zone boundaries there is still some confusion remaining, but the conditions are infinitely better than those of 75 years ago.

TIME, UNITS OF. The fundamental unit of time in all standard systems of physical units is the **second.**

TIMING AXIS OSCILLATOR. See **sweep oscillator.**

TIN. Metallic element. Symbol Sn (Stannum). Atomic number 50.

TINT. A mixture of a color with white.

TINT OF PASSAGE. Color produced by a non-colored plate placed between crossed **polarizers,** if the plate rotates the **plane of polarization** through an angle which depends on the number of wavelengths of light in the thickness of the plate. Suppose, for example, that a piece of quartz has a thickness such that rotation is 90° for a wavelength of light in the green-yellow region, that is, about 5600 A Suppose that this piece of quartz is inserted between a polarizer and an analyzer,

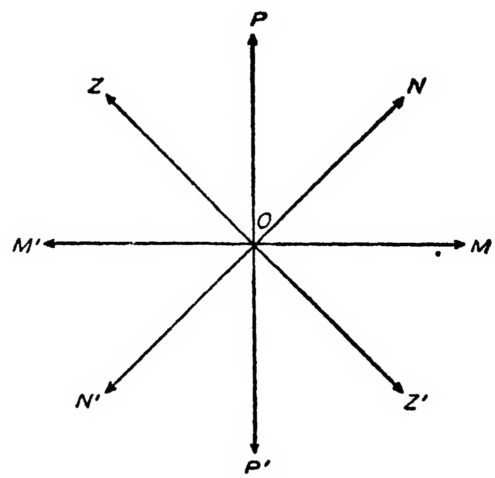


Diagram to show the meaning of tint of passage when a piece of quartz cut with faces perpendicular to the optic axis is placed between an analyzer and a polarizer. (By permission from "Introduction to Optics, Geometrical and Physical" by Robertson, 4th Ed., Copyright 1954, D. Van Nostrand Co., Inc.)

the vibration plane of the former being represented by POP′ plane in the figure. In the same figure, then the vibration plane for light

of wavelength 5600 A on emergence from the crystal is represented by MOM′, the angle POM being equal to 90°. For a longer wavelength, 6000 A, for example, the vibration plane is represented by NON′ the angle PON being considerably less than 90°. For a shorter wavelength such as 5200 A, the vibration plane is rotated through a greater angle, and hence is represented by ZOZ′.

If, now, the analyzer is turned so that its vibration plane is parallel to that of the polarizer, light of wavelength 5600 A is completely cut off, the resultant shade of the transmitted light being a grayish-violet. A slight rotation one way from this position evidently increases the transmitted intensity of 6000 A and other wavelengths toward the red end of the spectrum, but decreases that of 5000 A and the shorter waves at the blue end The grayish-violet tint is then replaced by a deep pink. A slight rotation in the opposite direction, however, decreases the intensity of the longer waves, increasing that of the shorter, and so causes a quick change from the grayish-violet to a deep blue. As the contrast between pink and blue is very marked and takes place as the result of a slight rotation, the gray-violet shade is called the tint of passage or sensitive tint. Because of this fact, even with white light as a source it is possible to set an analyzer in a critical position, if a piece of quartz of such a thickness is placed before it.

TINTOMETER. A widely used type of **colorimeter,** in which the intensity of color, and hence the concentration of the colored substance in a colored solution, is determined by comparison with colored glass slides or standard solutions.

TINTOMETER, LOVIBOND. An empirical colorimeter (see **colorimeter, empirical**) in which light to match a sample is passed successively through three glass filters, each of which is chosen from a series (yellow, red and blue) to effect the best possible match

TISELIUS METHOD. See **electrophoresis by Tiselius method.**

TITANIUM. Metallic element. Symbol Ti. Atomic number 22.

TM$_{m,n,p}$ RESONANT MODE (IN CYLINDRICAL CAVITY). See **resonant mode, TM$_{m,n,p}$ (in cylindrical cavity).**

TM$_{m,n}$ WAVE (IN CIRCULAR WAVEGUIDE). See **wave, TM$_{m,n}$ (in circular waveguide).**

TOEPLER-HOLTZ MACHINE. See **static machines.**

TOMONAGA-SCHRÖDINGER EQUATION. Equation of motion of the **state vector** of a quantized field $\phi(x)$, expressed in a covariant form by giving a prescription for finding ϕ on a **space-like surface** $\sigma(x)$ when it is specified on another such surface which is infinitesimally close.

$$i\hbar \frac{\partial \Phi}{\partial \sigma(x)} = H(x)\Phi.$$

(See also **Schrödinger equation.**)

TON. In the United States, a unit of weight equal to 2000 pounds (short ton). The long ton is equal to 2240 pounds and is more widely used in England The metric ton is equal to 1000 kilograms

TONE. (1) A sound wave capable of exciting an auditory sensation having pitch (2) A sound sensation having pitch

TONE ARM. A name sometimes given a **phonograph arm.**

TONE, COMPLEX. (1) A sound wave produced by the combination of simple sinusoidal components of different frequencies. (2) A sound sensation characterized by more than one pitch

TONES, COMBINATION. Due to **distortion** in the ear, the vibrations received in the **cochlea,** with the consequent sensations, do not accurately represent the periodic variations of the air pressure in the auditory canal, and sounds are heard subjectively which have no external physical existence When two pure musical tones (see **tone, simple**) are sounded, many persons can hear other tones in addition to the two actual ones These subjective sensations are called combination tones, from the fact that they correspond in pitch to tones having frequencies equal to the difference, to the sum, or to other simple combinations of the two actual frequencies. It was formerly supposed that the difference tone was the effect of **beats,** but Helmholtz detected the sum tone, and showed, further, that the difference tone sensation is too loud to be attributed to beats.

TONE CONTROL. The control for regulating the **frequency response** of an audio **amplifier.** In its most common form as found in most radio **receivers** it consists of a condenser in series with a variable resistance shunted across the circuit at some point. Since such a combination passes high frequencies more easily than low values, the highs will be attenuated, the degree being determined by the setting of the variable resistance. Thus by varying the resistance more or less attenuation may be given the high frequencies and the effect is as if the bass response were being varied. In more elaborate tone controls separate bass and treble controls are provided, thus allowing a balanced control of the response.

TONE, FUNDAMENTAL. (1) The component in a periodic wave corresponding to the fundamental frequency. (See **frequency, fundamental.**) (2) The component tone of lowest pitch in a complex tone. (See **tone, complex.**)

TONE, SEMI- (HALF STEP). The interval between two sounds whose basic frequency ratio is approximately equal to the twelfth root of two. The interval, in equally tempered semitones, between any two frequencies, is 12 times the logarithm to the base 2 (or 39.86 times the logarithm to the base 10) of the frequency ratio. (See also **scale, equally-tempered,** and **scale, just.**)

TONE, SIMPLE (PURE TONE). (1) A sound wave, the instantaneous sound pressure of which is a simple sinusoidal function of the time. (2) A sound sensation characterized by its singleness of pitch.

TONE, WARBLE. A pure tone (see **tone, simple**) whose frequency is modulated according to some regular pattern.

TONE, WHOLE (WHOLE STEP). The interval between two sounds whose basic frequency ratio is approximately equal to the sixth root of two. (See also **scale, equally-tempered,** and **scale, just.**)

TONES, AEOLIAN. The tones produced when a current of air strikes a stretched wire normal to its length. (See **Strouhal formula.**)

TONES, SUMMATION AND DIFFERENCE. Discussed under combination tone. (See **tone, combination.**)

TONES, SUSTAINED. Tones that are sounded for a sufficiently long interval that steady-state conditions can be assumed in the room in which they are sounded.

TOP, MOTION OF. See **precession; nutation.**

TOP, "SLEEPING." A top is said to "sleep" when it rotates with constant angular speed about its axis in a vertical position with neither **precession** nor **nutation.**

TORIC LENS. See **lens, toric.**

TORNADOES. Some thunderstorms, particularly the line-squall type, occasionally develop a violent whirl of air which extends down from the base of the cloud and touches the earth. It often draws up into the cloud again and may strike some distance away or never reappear. Very low pressure prevails inside a tornado because of its great **vorticity.**

TOROIDAL COORDINATES. A **curvilinear system** closely related to **bipolar coordinates.** If the traces of the surfaces in that system are taken in the XY-plane as two families of mutually orthogonal circles, then rotation of the circles about the Z-axis forms a family of **spherical surfaces** and a family of **anchor rings.** The toroidal coordinate surfaces are then taken as: (1) spherical, with centers on the Z-axis at a distance of $\pm a \cot \xi$ from the origin and with radii of $a \csc \xi$, $\xi = \text{const.}$; (2) anchor rings with radii of $a \coth \eta$ for the axial circles and circular cross sections of radii $a \operatorname{csch} \eta$, $\eta = \text{const.}$; (3) planes through the Z-axis, $\psi = \text{const.}$, where $\psi = \tan^{-1} y/x$. These coordinates are related to rectangular coordinates by the equations

$$x = r \cos \psi, \quad y = r \sin \psi$$

$$r = \frac{a \sinh \eta}{\cosh \eta - \cos \xi}; \quad z = \frac{a \sinh \xi}{\cosh \eta - \cos \xi};$$

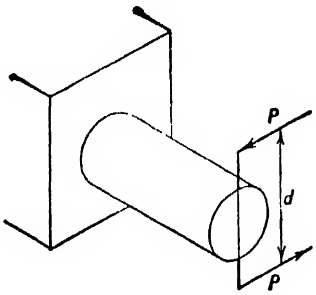
$$0 \leq \xi \leq 2\pi; 0 \leq \psi \leq 2\pi; 0 \leq \eta \leq \infty.$$

TORQUE. (1) For a single particle the torque is the moment of the resultant force on the particle with respect to a particular origin. This is expressed by the vector relation $\mathbf{L} = \mathbf{r} \times \mathbf{F}$, where $\mathbf{L}$ is the torque, $\mathbf{r}$ is the position vector with respect to the origin, and $\mathbf{F}$ is the resultant force. The torque is equal to the time rate of change of the moment of

momentum. (2) For a rigid body the torque with respect to a set of axes is expressed by the relation

$$\mathbf{L} = \int_v \mathbf{r} \times \mathbf{F}_v dv,$$

where $\mathbf{F}_v$ is the resultant force per unit volume due to external forces on the element dv and $\mathbf{r}$ is the position vector of the volume element. (See **moment of force.**) For a rigid body undergoing free rotation about a single axis, the torque $\mathbf{L} = I\boldsymbol{\alpha}$, where I is the moment of inertia and $\boldsymbol{\alpha}$ is the angular acceleration (3) In engineering mechanics usage a torque



often refers to the torsional or twisting moment or couple which tends to twist a rigidly fixed object such as a shaft about an axis of rotation. In the accompanying illustration a shaft of diameter d is connected to a rigid support. The forces $\mathbf{P}$ form a couple with a torque $L = Pd$ and tend to rotate the shaft in a counterclockwise direction

TORQUE AMPLIFIER. A device possessing input and output shafts and supplying work to rotate the output shaft, without imposing any significant torque on the input shaft. The speed of the output shaft is equal or proportional to that of the input shaft, regardless of the load on the former.

TORQUE OF CHARGED SYSTEM. See **force of a charged system.**

TORQUE ON A RIGID CIRCUIT. See **force on a rigid circuit.**

TORRICELLI LAW. The velocity of efflux from an **orifice** in a container of liquid is equal to the velocity attained by a body falling freely from rest a distance equal to the depth of the orifice below the free surface

TORSION. The twisting of a solid cylinder about its axis of symmetry It is measured by the angle through which the radius of any chosen circular section of the cylinder is rotated from its equilibrium position.

TORSION-HEAD WATTMETER. See **wattmeter, torsion-head.**

TORUS. See **anchor ring.**

TOTAL EMISSIVITY. See **emissivity.**

TOTAL HEAD TUBE. A tube inserted in a flow to measure the **stagnation pressure** or the total head. (See **pitot tube.**)

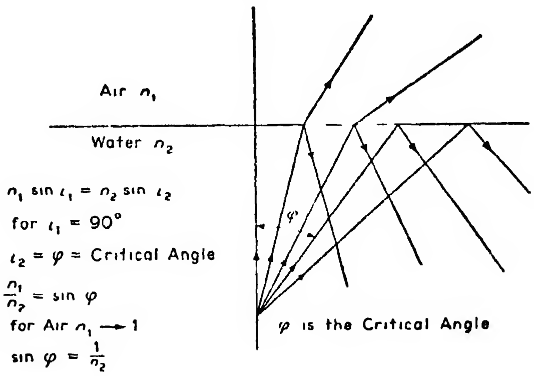
TOTAL INTERNAL REFLECTION. See **total reflection.**

TOTAL IONIZATION. See **ionization, total.**

TOTAL RADIANT EMITTANCE. See **emittance.**

TOTAL-REFLECTING PRISM. See **prism, total-reflecting.**

TOTAL REFLECTION. No conventional mirror will ever reflect all of the radiation striking it (See **reflection coefficient.**) However, radiation in a more dense medium, meet-



ing the boundary of a less dense medium at an angle greater than the critical angle, will be totally reflected back into the more dense medium. The critical angle is

$$\varphi_c = \sin^{-1} \frac{n_2}{n_1}$$

where n_1 is the **index of refraction** of the medium in which the radiation is incident and n_2 that of the second medium.

TOTAL STRESS ON SURFACE (IN ELECTRIC FIELD). The mutual repulsions of the elements of charge on a charged body, say

a sphere, produce a tensile stress tending to expand the body. A sphere of radius r, and charge Q has the potential

$$V = Q/\kappa r$$

where κ is the **dielectric constant** of the surrounding medium (unrationalized units). The increase of energy upon the addition of charge dQ is

$$dU = VdQ = \frac{QdQ}{\kappa r}$$

so that

$$U = \tfrac{1}{2}Q^2/\kappa r.$$

If now the sphere is allowed to expand under the effects of the radial stress S (per unit area of surface)

$$dU = \frac{QdQ}{\kappa r} - 4\pi r^2 S dr$$

so that for constant Q:

$$\left(\frac{\partial U}{\partial r}\right)_Q = -4\pi r^2 S$$

but

$$\left(\frac{\partial U}{\partial r}\right)_Q = -\frac{1}{2}\frac{Q^2}{\kappa r^2}$$

so

$$S = \frac{Q^2}{8\pi\kappa r^4}.$$

Now

$$Q = 4\pi r^2 \sigma$$

where σ is the surface charge density, hence

$$S = 2\pi\sigma^2/\kappa.$$

TOTAL TELEGRAPH DISTORTION. See **distortion, total telegraph.**

TOURMALINE. A natural mineral with **double-refracting** crystals, and the added property that the two rays are absorbed very unequally. The use of tourmaline because of its dark color has been largely replaced by the use of **"polaroid."**

TOWNSEND AVALANCHE. A term used in **counter** technology to describe a process which is essentially a cascade multiplication of ions. In this process an ion produces another ion by collision, and the new and original ions produce still others by further collisions, resulting finally in an "avalanche" of ions (or electrons). The terms "cumulative ionization" and "cascade" are also used to describe this process. It occurs in a **non-self-maintained gas discharge,** where ions have sufficient energy.

TOWNSEND COEFFICIENT, FIRST (α). The number of **ion pairs** formed by an electron in each centimeter of drift toward the central wire of a **counter.** It is a function of the field strength, the nature of the gas, and the gas pressure. An empirical formula due to Townsend is

$$\alpha = Ape^{-Bp/E}$$

where A and B are experimentally determined constants, E is the field, p the pressure, and α is the first Townsend coefficient, equal to the number of electrons released by an initial electron in traveling one centimeter through the **Townsend discharge.**

TOWNSEND DISCHARGE. A non-self-sustained gas discharge. (See **gas discharge, non-self-sustained.**)

TOWNSEND THEORY. The theory describing the formation of an electron avalanche in a counter. (See **Townsend avalanche.**)

TRACE. The sum of the diagonal elements of a **matrix,** indicated by $Tr\ \mathbf{A} = \Sigma A_{ii}$. Its properties include $Tr\ \mathbf{AB} = Tr\ \mathbf{BA}$; $Tr\ \mathbf{C} = Tr\ \mathbf{A} \cdot Tr\ \mathbf{B}$, where $\mathbf{C} = \mathbf{A} \times \mathbf{B}$, the **direct product.** Also called *Spur* from the German word When a matrix is a **representation** of a **group,** its trace is called the **character** of the representation.

TRACE INTERVAL. See **interval, trace.**

TRACER. A foreign substance mixed with or attached to a given substance to enable the distribution or location of the latter to be determined subsequently. A physical tracer is one that is attached by purely physical means to the object being traced. A chemical tracer is one that has chemical properties which are similar to those of the substance being traced and with which it is mixed homogeneously. A radioactive tracer is a physical or chemical tracer having radioactivity as its distinctive property. An isotopic tracer is a radionuclide or an **allobar** used as a chemical tracer for the element with which it is isotopic.

TRACKING. (1) The maintenance of proper frequency-relations in circuits designed to be simultaneously varied by gang operation. (2)

The process of keeping radio beams set on a target. A motion given to the major lobe (see **lobe, major**) of an antenna, such that some pre-assigned moving target in space is always contained within the major lobe (3) The following of a groove by a phonograph needle. (4) The process of causing an index to follow the variation of a quantity by means of an **inverse feedback** (servo) **loop.**

TRAILING EDGE. The major portion of the decay of a **pulse.**

TRAILING EDGE PULSE TIME. See **pulse time, trailing edge.**

TRAJECTORY. A path in space which a particle or system traverses. The forces acting on the particle or system determine this path.

TRAJECTORY OF AIR PARCELS. A parcel of air located in a given pressure field will move with the gradient wind of the field (assuming steady flow). At the end of a few hours, the parcel will locate in some new region where it has been carried by the wind If, however, the pressure field and therefore the wind is changing, the parcel will not move into a position indicated by the existing gradient flow. It will follow a trajectory or path dictated by successive gradient directions and velocities as indicated by **synoptic charts.** An approximation to its trajectory can be had by extrapolating the parcel's indicated movement for as small a time interval as practicable (usually 3 or 6 hours between synoptic charts) using successive synoptic charts.

TRANCOR. Trade name for a highly-oriented, 3% silicon-iron magnetic alloy.

TRANSADMITTANCE. See **interelectrode transadmittance.**

TRANSADMITTANCE, BEAM. In velocity-modulated electron tubes, the ratio of the fundamental component of beam-current through the output gap, to the fundamental component of the voltage applied to the stream at the input gap.

TRANSADMITTANCE, OVERALL. In velocity-modulated electron tubes, the ratio of the load current developed by the beam to the actual beam current, multiplied by the beam transadmittance. (See **transadmittance, beam.**)

TRANSCEIVER. A portable device which can perform both the functions of transmission and reception of radio communications.

TRANSCENDENTAL. A term for **numbers, equations,** or **functions** which are not **algebraic.**

TRANSCONDUCTANCE. As most commonly used, the interelectrode transconductance between the control grid and the plate. At low frequencies, transconductance is the slope of the control-grid-to-plate transfer characteristic. More generally, the transconductance may be defined as the ratio of the change in the current flowing from one pair of terminals, these terminals being short-circuited, to the change in the potential difference across another pair of terminals. All changes are assumed small.

TRANSCONDUCTANCE, CONVERSION (OF A HETERODYNE CONVERSION TRANSDUCER). The quotient of the magnitude of the desired output-frequency component of current by the magnitude of the input-frequency component of voltage when the impedance of the output external termination is negligible for all the frequencies which may affect the result. Unless otherwise stated, the term refers to the cases in which the input-frequency voltage is of infinitesimal magnitude All direct electrode voltages and the magnitude of the local-oscillator voltage must be specified, fixed values.

TRANSCRIBER. Equipment associated with a **computing** machine for the purpose of transferring input (or output) data from a record of information in a given language to the medium and the language used by a digital computing machine; or from a computing machine; or from a computing machine to a record of information.

TRANSDUCER. (1) A device by means of which energy can flow from one or more transmission systems to one or more other transmission systems. The energy transmitted by these systems may of any form (for example, it may be electric, mechanical, or acoustical), and it may be of the same form or different forms in the various input and output systems. (2) For some purposes the transducer is defined (more narrowly) as a device capable of being actuated by waves from one or more transmission systems or media, and

of supplying related waves to one or more other transmission systems or media. It is sometimes implied that the input and output energies shall be of different forms. E.g., an electroacoustic transducer accepts electrical waves and delivers acoustic waves.

TRANSDUCER, ACTIVE. A **transducer** whose output waves are dependent upon sources of power, apart from that supplied by any of the actuating waves, which power is controlled by one or more of these waves.

TRANSDUCER, BILATERAL. A **transducer** capable of transmission simultaneously in both directions between at least two terminations.

TRANSDUCER, CONVERSION. An electric transducer in which the input and the output frequencies are different. If the frequency-changing property of a conversion transducer depends upon a generator of frequency different from that of the input or output frequencies, the frequency and voltage or power of this generator are parameters of the conversion transducer.

TRANSDUCER DISSIPATION LOSS. For a **transducer** operating between specified source and load, the ratio of the power delivered by the specified source when the transducer is connected to the specified load, to the power available from the transducer when connected to the specified source. If the input power, or the output power, or both consist of more than one component, the particular components used must be specified. This ratio is usually expressed in **decibels.**

TRANSDUCER, DISSYMMETRICAL (DISSYMMETRICAL NETWORK). A **transducer** whose input and output image impedances (see **impedances, image**) are not equal. (2) A transducer in which the interchange of at least one pair of specified terminations will change the transmission.

TRANSDUCER, ELECTRIC. A **transducer** in which all of the waves concerned are electric.

TRANSDUCER, ELECTROACOUSTIC. A **transducer** for receiving waves from an electric system and delivering waves to an acoustic system, or vice versa.

TRANSDUCER, ELECTROMECHANICAL. A **transducer** for receiving waves from an electric system and delivering waves to a mechanical system, or vice versa.

TRANSDUCER EQUIVALENT NOISE PRESSURE (EQUIVALENT NOISE PRESSURE). For an acoustical-electrical transducer or system used for sound reception, the root-mean-square sound pressure (see **sound pressure, effective**) of a sinusoidal plane progressive wave, which, if propagated parallel to the principal axis of the transducer, would produce an open-circuit signal voltage equal to the root-mean-square of the inherent open-circuit noise voltage of the transducer in a transmission band having a band width of 1 cycle per second and centered on the frequency of the plane sound wave. If the equivalent noise pressure of the transducer is a function of secondary variables, such as ambient temperature or pressure, the applicable value of these quantities should be stated explicitly.

TRANSDUCER GAIN. The ratio of the power that the **transducer** delivers to the specified load under specified operating conditions to the available power of the specified source. If the input and/or output power consist of more than one component, such as multifrequency signal or noise, then the particular components used and their weighting should be specified. This **gain** is usually expressed in **decibels.**

TRANSDUCER, HARMONIC CONVERSION. A conversion transducer (see **transducer, conversion**) in which the useful output frequency is a multiple or a submultiple of the input frequency. Either a **frequency multiplier** or a **frequency divider** is a special case of harmonic conversion transducer.

TRANSDUCER, HETERODYNE CONVERSION (CONVERTER). A conversion transducer (see **transducer, conversion**) in which the useful output frequency is the sum or difference of the input frequency and an integral multiple of the frequency of another wave.

TRANSDUCER, IDEAL. An hypothetical passive transducer (see **transducer, passive**) which transfers the maximum possible power from a specified source to a load. In linear electric circuits and analogous cases, this is equivalent to a transducer which (a) dissi-

pates no energy and (b) when connected to the specified source and load, presents to each its conjugate.

TRANSDUCER, LINEAR. A **transducer** for which the pertinent measures of all the waves concerned are linearly related. By "linearly related" is meant any relation of linear character whether by linear algebraic equation or by linear differential equation or by other linear connection. The term "waves concerned" connotes actuating waves and related output waves, the relation of which is of primary interest in the problem at hand.

TRANSDUCER LOSS. The ratio of the available power of the specified source to the power that the **transducer** delivers to the specified load under specified operating conditions. If the input power, or the output power, or both consist of more than one component, the particular components used must be specified. This ratio is usually expressed in **decibels.** The transducer loss is made up of a transition loss between the transducer and the load, and a dissipation loss within the transducer.

TRANSDUCER, MODE (MODE TRANSFORMER). A device for transforming an electromagnetic wave from one mode of propagation to another.

TRANSDUCER, PASSIVE. A **transducer** whose output waves are independent of any sources of power which is controlled by the actuating waves.

TRANSDUCER POWER AMPLIFICATION. See **amplification, power** (3).

TRANSDUCER PULSE DELAY. The interval of time between a specified point on the input pulse and a specified point on the related output pulse. This is a general term which applies to the pulse delay in any **transducer,** such as **receiver, transmitter, amplifier, oscillator,** and the like. Specifications may require illustrations.

TRANSDUCER, RECIPROCAL. A **transducer** which satisfies the principle of **reciprocity.** (See **reciprocity theorem, acoustical;** and **reciprocity theorem, electroacoustical.**)

TRANSDUCER, REVERSIBLE. A **transducer** in which the **transducer loss** is independent of the direction of transmission.

TRANSDUCER, SYMMETRICAL. (1) A **transducer** whose input and output image impedances (see **impedances, image**) are equal. (2) A transducer in which all possible pairs of specified terminations may be interchanged without affecting transmission.

TRANSDUCER, TIME-SELECTION. See **time-selection transducer.**

TRANSDUCER, UNILATERAL. A **transducer** which cannot be actuated at its outputs by waves in such a manner as to supply related waves at its inputs.

TRANSDUCTOR. The name frequently applied, in Europe, to a **saturable reactor.**

TRANSFER ADMITTANCE (FROM THE jTH TERMINAL TO THE kTH TERMINAL OF AN n-TERMINAL NETWORK). The quotient of the complex alternating component I_k of the current flowing to the kth terminal from the kth external termination by the complex alternating component V_j of the voltage applied to the jth terminal with respect to the reference point when all other terminals have arbitrary external terminations.

TRANSFER CHARACTERISTIC. In electron tubes, a relation, usually shown by a graph, between the voltage of one electrode and the current to another electrode, all other electrode voltages being maintained constant.

TRANSFER CONSTANT. (1) Of a transducer, one-half the natural logarithm of the complex ratio of the steady-state product of the force and the velocity, or the pressure and **volume velocity,** or the voltage and current entering the **transducer** to that leaving the transducer when the latter is terminated in an image impedance (see **impedances, image**). (2) Of a network, one-half the natural logarithm of the complex ratio of the steady-state volt-amperes entering and leaving the network, when the latter is terminated in its **image impedance.**

TRANSFER CURRENT (OF A GLOW-DISCHARGE COLD-CATHODE TUBE). The starter-gap current required to cause conduction across the main **gap.** The transfer current is a function of the anode voltage.

TRANSFER IMPEDANCE. See **impedance, transfer.**

TRANSFER (OF CONTROL) INSTRUCTION. In computer terminology, an **instruction** which (conditionally or unconditionally) causes the next instruction word to be selected from a specified memory location.

TRANSFERENCE NUMBER (OR TRANSPORT NUMBER). The transport number of a given **ion** in an **electrolyte** is the fraction of total current carried by that ion.

TRANSFERENCE NUMBER, METHODS FOR. See **sheared boundary method; moving boundary method; Hittorf method.**

TRANSFORM. (1) If A, B, X are three **matrices** or three elements of a **group,** then $B = X^{-1}AX$ is the **transform** of A by X and A, B are **conjugate** to each other. The complete set of group elements which are conjugate to each other form a **class** of the group. (2) An **integral equation** of the first kind,

$$g(z) = \int K(x,z)f(x)dx$$

is called the **transform** of $f(x)$. Special cases are the **Euler, Fourier, Laplace, Hankel, Mellin,** etc., transforms.

TRANSFORMATION. A change of variables in an algebraic expression. If interpreted geometrically it is a **map** or mapping. Matrix notation is frequently convenient for discussing transformations.

TRANSFORMATION, AFFINE. A transformation (i.e., change of algebraic variables) of the form $x' = a_1x + b_1y + c_1$; $y' = a_2x + b_2y + c_2$. If the **determinant** of the coefficients, $\Delta = a_1b_2 - a_2b_1 \neq 0$, special cases of it are translations, rotations, reflections in the axes, strains, elongations, and compressions. Parallel lines or finite points are transformed into similar configurations; the line at infinity remains fixed. If $\Delta = 0$, the transformation is **singular.**

TRANSFORMATION, CANONICAL. A transformation from one set of generalized **coordinates and momenta** to a new set such that the form of the **canonical equations of motion** is preserved. This usually involves finding a transformation function S which is a continuous and differentiable function of the old and new generalized coordinates and the time. The transformation can be defined by

$$L(q,\dot{q}) = L'(Q,\dot{Q}) + \frac{dS}{dt}$$

where L is the Lagrangian function in original set of coordinates, and L' is the Lagrangian function in the transformed set of coordinates. (Cf. **canonical equation of motion; Lagrangian function.**)

TRANSFORMATION CIRCLE. In **impedance matching,** a circle on a complex frequency plane which may be transformed by various impedance-changing schemes to coincide with the **definition circle.**

TRANSFORMATION, COLLINEATORY. Two **matrices** so related that one is the **transform** of the other:

$$\mathbf{B} = \mathbf{X}^{-1}\mathbf{AX},$$

where $\mathbf{X}^{-1}$ is the **reciprocal** to **X**. (Also called, from the German, *Ähnlichkeitstransformation*.)

TRANSFORMATION, CONGRUENT. Two **matrices** so related that $\mathbf{B} = \tilde{\mathbf{X}}\mathbf{AX}$, where $\tilde{\mathbf{X}}$ is the **transpose** of **X**.

TRANSFORMATION, CONJUNCTIVE. Two **matrices** so related that $\mathbf{B} = \mathbf{X}^{\dagger}\mathbf{AX}$, where $\mathbf{X}^{\dagger}$ is **Hermitian** to **X**. If the matrices are all real, the transformation is also congruent. (See **transform, congruent.**)

TRANSFORMATION CONSTANT. A synonym for **disintegration constant.**

TRANSFORMATION, CONTACT. A transformation which transforms line elements (position and direction) rather than points. The law of transformation from (x,y,z) to new coordinates (x',y',z') is expressed as

$$\int f(x,y,z;\, x',y',z')d\tau = \text{const.}$$

When

$$\dot{x}\partial S/\partial x + \dot{y}\partial S/\partial y = 0$$

and

$$\dot{x}'\partial S/\partial x' + \dot{y}'\partial S/\partial y' = 0,$$

then S is a **contact transformation.**

TRANSFORMATION, LINEAR. A change in variable, conveniently given in **matrix** form as $\mathbf{x}' = \mathbf{Rx}$ (see **vector**). A more gen-

eral relation is the **linear fractional transformation** which is a **mapping** or transformation in the complex plane

$$w = \frac{az + b}{cz + d}; \quad (ad - bc) \neq 0$$

where a, b, c, d are constants, real or complex. A circle in the z-plane is transformed into a circle in the w-plane. A straight line transforms in the same way, for it may be regarded as a special case of a circle. Since there are only three independent constants in the transformation, any three points z_1, z_2, z_3 are images of w_1, w_2, w_3. Thus the points in the z-plane become 0, 1, ∞ by the transformation

$$w = \frac{(z_2 - z_3)(z - z_1)}{(z_2 - z_1)(z - z_3)}.$$

Other terms used for this type of transformation are Möbius, general bilinear, and homographic transformation.

TRANSFORMATION, REAL ORTHOGONAL. A transform which is both collineatory and congruent

$$\mathbf{B} = \tilde{\mathbf{X}}\mathbf{A}\mathbf{X} = \mathbf{X}^{-1}\mathbf{A}\mathbf{X}.$$

TRANSFORMATION SERIES. Synonym for **radioactive series.**

TRANSFORMATION, SIMILARITY. See **transformation, collineatory.**

TRANSFORMATION, UNITARY. A transformation which is both collineatory and conjunctive (see **transformation, collineatory** and **transformation, conjunctive**)

$$\mathbf{B} = \mathbf{X}^{\dagger}\mathbf{A}\mathbf{X} = \mathbf{X}^{-1}\mathbf{A}\mathbf{X}.$$

TRANSFORMER. A device for transferring electric energy from a circuit to another by magnetic **induction,** usually with a change of voltage. There are no moving parts, nor is there any electrical connection of the two circuits (except in the case of the auto-transformer); the energy is transferred through magnetic linkage. Regardless of the voltage, the energy supply circuit is termed the primary, and the energy receiving circuit the secondary.

Transformers may be classed as follows:

1. According to purpose.
   - *a.* Constant voltage ratio.
   - *b.* Constant current.
   - *c.* Feeder voltage regulation.
2. According to use.
   - *a.* Heavy duty. Power type as used in substations.
   - *b.* Distribution. At customer end of the distribution system.
   - *c.* Instrument. Potential and current transformers of small capacity and light weight, but having accurate ratios and phase relationships between input and output.
3. According to arrangement of magnetic circuit.
   - *a.* Shell type. Large, low-voltage units.
   - *b.* Core type. Small, high-voltage units.
4. According to arrangement of electric circuit.
   - *a.* Single- or three-phase. Small transformers are often three-phase, but large capacity is met by the three-phase connection of three single-phase transformers.
   - *b.* Connection of three-phase windings. Δ to Δ, Δ to Y, Y to Y, open Δ. (See **delta connection; Y connection.**)
5. According to cooling
   - *a.* Air-cooled.
   - *b* Oil-filled. Oil-cooled by direct radiation or by heat transfer to separate water-cooling system.
   - *c* Pyranol-filled

TRANSFORMER, COUPLING. See **coupling transformer.**

TRANSFORMER FILTER. A **filter** which provides at all frequencies a certain transformation (step-up or step-down) in **impedance,** in addition to having **attenuation-constant** and **phase-constant** characteristics.

TRANSFORMER, IDEAL. (1) A hypothetical **transformer** which neither stores nor dissipates energy. Its self-inductances have a finite ratio, and unity coefficient of coupling. Its self- and mutual-impedances are pure inductances of infinitely great value. An ideal transformer satisfies the following relations:

$$E_1 = nE_2$$

$$I_1 = I_2/n$$

and transforms **load impedances** by the factor n^2. (2) An ideal transformer may also be defined as a transformer employing ideal core or cores operating in the unsaturated region of the core characteristic, having perfect cou-

pling between windings and further characterized by absence of winding resistances, losses, and capacitances.

TRANSFORMER, INTERPHASE. See **interphase transformer.**

TRANSFORMER LOSS. The ratio of the power that would be delivered to a specified load impedance if an ideal transformer (see **transformer, ideal**) were substituted for the actual transformer, to the power delivered to the specified load impedance by the transformer, under the condition that the **impedance ratio** of the ideal transformer is equal to that specified for the transformer. If the input and/or output power consist of more than one component, such as multifrequency signal or noise, then the particular components used and their weighting must be specified. This loss is usually expressed in decibels.

An older definition of transformer loss, which is now deprecated, is the loss which would be eliminated by the insertion, at any point in a transmission system, of an ideal transformer having an impedance ratio equal to the absolute value of the ratio of the impedances facing the transformer.

TRANSFORMER, MATCHING. See **matching transformer.**

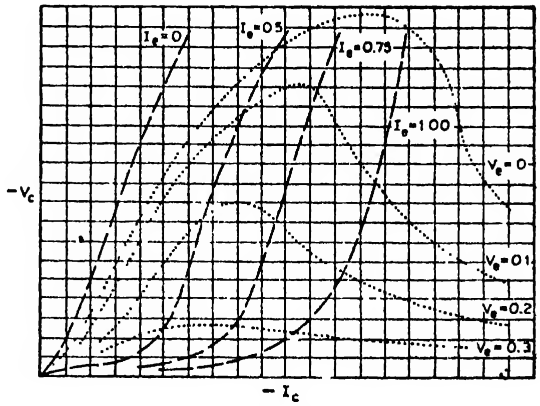
TRANSFORMER, WAVEGUIDE. See **waveguide transformer.**

TRANSIENT. (1) That part of the forced oscillation (see **oscillation, forced**) of a linear system which decays more or less rapidly after the imposition of the force; to be distinguished from the steady state. (See **decay modulus; logarithmic decrement.**) (2) The non-permanent terms in the response of an **electric network** to a stimulus. (See **state, steady.**)

TRANSIENT MOTION. A motion which has not reached or has ceased to be a steady state. (See **state, steady.**)

TRANSIENT RESPONSE, ACOUSTIC. The response of an acoustical system to a suddenly impressed force or pressure.

TRANSISTOR. An electronic device for rectification and/or amplification consisting of a **semiconducting material** to which contact is made by three or more **electrodes,** which are usually metal points or by soldered junctions. In essence, a transistor consists of a rectifying junction between the **base** and the **collector.** Characteristic of such a junction is a



Transistor characteristic curves, V_c is collector voltage, I_c is collector current, V_e is emitter voltage and I_e is emitter current

space-charge layer. By injecting, from an **emitter,** carriers of the opposite sign, the current carried by the junction can be altered and controlled. This is realized in practice in various ways, as in the **type-A, filamentary,** and ***p-n* junction transistors.**

Compared with a vacuum tube, a transistor requires no heater current, is small and light, can be made mechanically rigid and long-lasting, and operates at low voltages with relatively high currents. However, **transit time** effects limit the frequency response, and the operating characteristics depend on temperature.

TRANSISTOR AMPLIFIER. See **amplifier, transistor.**

TRANSISTOR BASE RESISTANCE. See **transistor parameter r_b.**

TRANSISTOR, BIPOLAR. A transistor which utilizes charge **carriers** of both polarities.

TRANSISTOR COLLECTOR RESISTANCE. See **transistor parameter r_c.**

TRANSISTOR, CONDUCTIVITY MODULATION. A **transistor** in which the active properties are derived from **minority carrier** modulation of the bulk resistivity of a **semiconductor.**

TRANSISTOR CURRENT AMPLIFICATION. See **transistor parameter h_{21}.**

TRANSISTOR CURRENT GAIN. See **transistor parameter α.**

TRANSISTOR, DOUBLE-SURFACE. A point-contact transistor (see **transistor, point-contact**) in which the **emitter** and **collector** whiskers contact the opposite sides of the **base region.**

TRANSISTOR EMITTER RESISTANCE. See **transistor parameter r_e.**

TRANSISTOR, FILAMENTARY. A conductivity-modulation transistor (see **transistor, conductivity-modulation**) with a length much greater than its transverse dimensions.

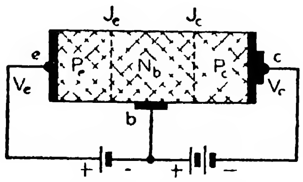
TRANSISTOR, HOOK-COLLECTOR. A tetrode junction transistor (P-N-P-N) which has a current amplification in excess of unity by virtue of the **"hook"** effect at the collector junction.

TRANSISTOR, INPUT IMPEDANCE. See **transistor parameter h_{11}.**

TRANSISTOR, JUNCTION. A **transistor** having a **base electrode** and two or more **junction electrodes.**

TRANSISTOR OUTPUT ADMITTANCE. See **transistor parameter h_{22}.**

TRANSISTORS, P-N JUNCTION, OR P-N-P TRANSISTOR. A **transistor** consisting of two ***p*-type** regions separated by an ***n*-type** region. When a small forward bias is applied to the first junction and a large negative bias



p-n junction transistor (or *p-n-p* transistor) (By permission from "Electrons and Holes in Semiconductors" by Shockley, Copyright 1950, D. Van Nostrand Co., Inc.)

to the second junction, the system behaves much like a vacuum-tube **triode.** (See figure.)

TRANSISTOR PARAMETER α. The current gain of a transistor which is equal to

$$\left(\frac{\partial I_c}{\partial I_e}\right)_{V_c=\text{constant}}.$$

TRANSISTOR PARAMETER h_{11}. The input impedance of a transistor with the output short-circuited:

$$h_{11} = \left(\frac{\partial V_e}{\partial I_e}\right)_{V_c=\text{constant}} = \frac{r_e r_b + r_c[r_e + r_b(1 - \alpha)]}{r_b + r_c}.$$

TRANSISTOR PARAMETER h_{12}. The voltage feedback ratio for a transistor with the input open-circuited:

$$h_{12} = \left(\frac{\partial V_e}{\partial V_c}\right)_{I_e=\text{constant}} = \frac{r_b}{r_b + r_c}.$$

TRANSISTOR PARAMETER h_{21}. The current amplification of a transistor with the output short-circuited:

$$h_{21} = -\left(\frac{\partial I_c}{\partial I_e}\right)_{V_c=\text{constant}} = -\alpha$$

TRANSISTOR PARAMETER h_{22}. The output admittance of a transistor with the input open-circuited:

$$h_{22} = \left(\frac{\partial I_c}{\partial V_c}\right)_{I_e=\text{constant}} = \frac{1}{r_b + r_c}.$$

TRANSISTOR PARAMETER r_b. The base resistance of a transistor is equal to:

$$\left(\frac{\partial V_e}{\partial I_c}\right)_{I_e=\text{constant}}.$$

TRANSISTOR PARAMETER r_c. The back-resistance of the collector-base diode of a transistor which is equal to:

$$\left(\frac{\partial V_c}{\partial I_c}\right)_{I_e=\text{constant}} - r_b.$$

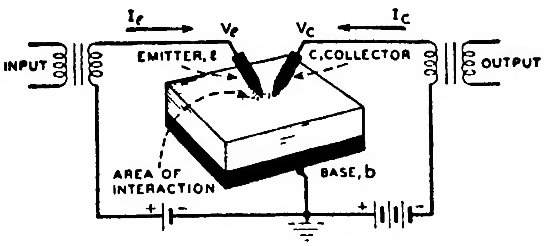
TRANSISTOR PARAMETER r_e. The emitter resistance or forward resistance of the emitter-base diode of a transistor is equal to

$$\left(\frac{\partial V_e}{\partial I_e}\right)_{I_c=\text{constant}} - r_b.$$

TRANSISTOR, POINT-CONTACT. A **transistor** having a **base electrode** and two or more **point-contact electrodes.**

TRANSISTOR, POINT-JUNCTION. A **transistor** having a **base electrode** and both **point-contact** and **junction electrodes.**

TRANSISTOR, TYPE A. A **transistor** in which **emitter** and **collector** are metallic point contacts spaced close together on the



Type A transistor (By permission from "Electrons and Holes in Semiconductors" by Shockley, Copyright 1950, D. Van Nostrand Co, Inc)

surface of **n-type semiconductor.** It depends for its action on the **holes** injected by the **emitter** into the neighborhood of the **collector.** (See figure.)

TRANSISTOR, UNIPOLAR. A **transistor** which utilizes charge **carriers** of only one polarity.

TRANSISTOR, VOLTAGE FEEDBACK RATIO. See **transistor parameter, h_{12}.**

TRANSIT ANGLE. The product of the **transit time** and the angular frequency.

TRANSIT INSTRUMENT. An astronomical instrument consisting essentially of a telescope mounted on a horizontal transverse axis, which is adjusted so as to be perpendicular to the plane of the meridian of a place. It is used for observing the exact time of the passage of a celestial body across the meridian.

TRANSIT TIME. The time required for electrons to pass between a given pair of electrodes.

TRANSIT TIME EFFECT. At low frequencies the **transit time** in a conventional triode, etc., is small compared to the period (transit angle is small). As higher frequencies are approached the electrons, because the **transit angle** may be an appreciable part of a cycle, act essentially as though they were out of phase with the grid signal resulting in a greatly increased grid-cathode conductance.

TRANSITION. (1) A change of form or external appearance. (2) A **change of state.** (3) A change of **phase.**

TRANSITION, ALLOWED. A transition between two states of a quantum-mechanical system marked by a comparative ease with which the change in quantum numbers involved can be accomplished. For example, transitions in which the total angular momentum quantum number changes by one in units of $\hbar$, are frequently allowed; and, other things being equal, a transition involving a change of one will take place with greater probability than a competing transition involving a change in this quantum number of two or more. (See **selection rules; forbidden transition.**)

TRANSITION CELL. An electrolytic **cell** containing an electrolyte which is undergoing a definite change in valence of one of the ions present, or of other nature, with a corresponding change in **electromotive force.**

TRANSITION EFFECT. A change in the intensity of the secondary radiation associated with a beam of primary radiation as the latter passes from a vacuum into a material medium, or from one medium into another.

TRANSITION ELEMENT. (1) An **element** which couples one type of transmission system to another, as a **coaxial line to waveguide.** (2) See **transition metal.**

TRANSITION, FIRST ORDER. A **transition** in which there is a discontinuous change in the first-order derivative of the Gibbs function (see **free energy** (1)), and which is accompanied by a **latent heat.**

TRANSITION, FORBIDDEN. See **forbidden transition.**

TRANSITION FREQUENCY (CROSSOVER FREQUENCY). Of a disk recording system, the frequency corresponding to the point of intersection of the asymptotes to the constant amplitude and the constant velocity portions of its frequency response curve. This curve is plotted with output voltage ratio in **decibels** as the ordinate and the logarithm of the frequency as the abscissa.

TRANSITION, ISOMERIC. See **isomeric transition.**

TRANSITION LOSS. In audio systems and components, the transition loss is defined as follows: At any point in a transmission system, the ratio of the available power from that part of the system ahead of the point under consideration to the power delivered to that part of the system beyond the point under consideration. If the input and/or output power consist of more than one component, such as multifrequency signal or noise, then the particular components used and their weighting should be specified. This loss is usually expressed in **decibels.**

In wave-propagation usage, transition loss is defined in one of two ways, as follows: (1) At a transition or discontinuity between two transmission media, the difference between the power incident upon the discontinuity and the power transmitted beyond the discontinuity which would be observed if the medium beyond the discontinuity were match-terminated. (2) The ratio in decibels of the power incident upon the discontinuity to the power transmitted beyond the discontinuity which would be observed if the medium beyond the discontinuity were match-terminated.

TRANSITION METAL. A member of one of several groups of elements in the **periodic table** having an incomplete **inner shell,** e.g., Fe, with only 6 out of 10 possible $3d$ electrons, and yet with 2 electrons in the $4s$ state. The magnetic properties of these elements are important, since the electron **spins** in the incomplete shell tend to line up **(Hund rule),** and hence have large magnetic moments.

TRANSITION MULTIPOLE MOMENTS. See **multipole moments.**

TRANSITION POINT. A point at which a system changes **phase.** Familiar examples are those of melting, vaporization, etc. These are first-order transitions (see **transition, first order**) in which there is a discontinuous change in the first-order derivatives of the Gibbs function (see **free energy (1)**) and which are accompanied by a latent heat. Examples of transitions of the second order are also known. (See **transition, second order.**)

TRANSITION PROBABILITY. The probability per unit time, symbol w_{if}, that a system in state i will undergo a transition to state f. The quantity

$$w_i = \left[\sum_{\substack{\text{over}\\ \text{all}\\ f}} w_{if}\right]$$

is the total transition probability for state i. The probability that the system is still in state i at the end of time t is then $e^{-w_i t}$. For radioactive transitions, the symbol λ is used instead of w_i, and the total transition probability is then called the **disintegration constant.**

TRANSITION REGION. The region, between two homogeneous **semiconductor** regions, in which the **impurity** concentration changes.

TRANSITION, SECOND ORDER. A transition in which there are discontinuous changes in the second-order derivatives of the Gibbs function (see **free energy (1)**). It is accompanied by a sharp peak in the **specific heat,** and in an ideal second-order transition there is no latent heat. Examples: the transition of helium I to helium II at 2.19°K; **superconductive** transition in the absence of a magnetic fluid; transition from **ferromagnetism** to **paramagnetism.**

TRANSITION ZONE. In meteorology, the relatively narrow region occupied by a **front** wherein the meteorological properties exhibit large variations over a short distance and possess values intermediate between those characteristic of the **air masses** on either side of the zone.

TRANSITRON OSCILLATOR. See **oscillator, transitron.**

TRANSLATION GROUP. The totality of operations by which a **crystal lattice** may be transformed into itself by bodily displacements without rotation.

TRANSLATION OPERATION. The geometrical process of displacing a body along a straight line, keeping lines fixed in the body always parallel to themselves.

TRANSLATIONAL PARTITION FUNCTIONS. See **partition function.**

TRANSMISSION ANOMALY. In underwater sound, the deviation of transmission from inverse square law propagation. The

transmission anomaly A in **decibels** is given by

$$A = H - 20 \log R,$$

where H = transmission loss in decibels, R = horizontal range in yards.

TRANSMISSION BAND (OF A UNICONDUCTOR WAVEGUIDE). The frequency range above the **cut-off frequency.**

TRANSMISSION COEFFICIENT. (1) In a transmission medium, at a given frequency, at a given point, and for a given mode of transmission, the ratio of some quantity associated with the resultant field, which is the sum of the incident and reflected waves, to the corresponding quantity in the incident wave. The transmission coefficient may be different for different associated quantities, and the chosen quantity should be specified. The "voltage transmission coefficient" is commonly used and defined as the complex ratio of the resultant electric field strength (or voltage) to that of the incident wave. (2) For a transition or discontinuity between two transmission media, at a given frequency, the ratio of some quantity associated with the transmitted wave at a specified point in the second medium to the same quantity associated with the incident wave at a specified point in a first medium, the second medium being **match-terminated.** (3) In atomic physics, transmission coefficient is a synonym for **penetration probability.** (4) For acoustical transmission coefficient, see **sound transmission coefficient.**

TRANSMISSION DENSITY, DIFFUSE. The value of the **photographic transmission density** obtained when the light flux impinges normally on the sample, and all the transmitted flux is collected and measured.

TRANSMISSION DENSITY, SPECULAR. The value of the **photographic transmission density** obtained when the light flux impinges normally on the sample, and only the normal component of the transmitted flux is collected and measured.

TRANSMISSION, DIPLEX RADIO. The simultaneous transmission of two signals using a common **carrier wave.**

TRANSMISSION EXPERIMENT. An experiment in which a sample of material is placed between a source of radiation and a detector that registers the intensity of the transmitted radiation as a function of, for example, the intensity of the incident radiation or the thickness of the absorbing material. Transmission experiments are commonly used in the measurement of the total cross sections for neutrons.

TRANSMISSION, FACSIMILE. The transmission by electrical means of any graphic material such as pictures, printed matter, maps, etc. There are three methods of transmission in use, transmission by radio, by land telephone lines and by submarine cable. Each of these introduces its own problems, but the fundamentals of the system are the same for all, the material must be broken into sequential elementary parts which may be transmitted by electrical means and then the parts converted back into a graphic presentation at the receiver. To be specific let us discuss the transmission of a picture although it should be kept in mind that exactly the same procedure applies to any graphic material. The picture is broken into the sequence of elemental parts by the process of **scanning.** This may be done by mounting the picture on a revolving drum and projecting a very small beam of light on or through it. The light is reflected (or transmitted) to a **phototube,** the light and hence the phototube output being proportional to the picture density. The light is moved along the picture (parallel to the axis of the drum) at such a rate that it displaces axially its own width for each revolution of the drum. Thus the spot of light progressively covers every spot on the picture. The output of the phototube is an electrical breakdown of the picture, and is then modified for transmission. For radio and land lines this means **modulation** upon a suitable **carrier.** There are several methods of doing this but these are merely details of the system. For submarine cable transmission the signal is amplified by d-c amplifiers and fed directly to the cable since these cables cannot handle high frequencies. At the receiving end the modulated signal is demodulated and fed to the recorder. This varies with different systems but two types are in wide use. One depends upon a variable light on a photographic paper or film. The light is varied in different ways, one being to use a specially constructed gas-filled lamp whose intensity varies with the signal, others use light valves,

but in each case the result is a spot of light whose intensity varies with the picture focused on the paper. There are some direct-developing papers, but others require a development process after removal from the receiver. The other method of recording is to utilize a paper sensitized to electrical current passage and to pass the received signal current (after detection, of course) through it. Regardless of the method of recording it is necessary for the receiver to be synchronized with the transmitter. Sometimes this is accomplished by depending upon the stability of the power systems and the use of synchronous motor drives; other methods involve the transmission of synchronizing pulses periodically. Facsimile transmission has a wide field of application in the transmission of news pictures, legal documents, maps, etc.

TRANSMISSION GRATING. A **diffraction grating** ruled on a transparent base. (Most transmission gratings are plastic replicas of **reflection gratings.**) The radiation is transmitted through, rather than reflected from such a grating.

TRANSMISSION LEVEL. The level of the **signal power** at any point in a transmission system which is the ratio of the power at that point to the power at some point in the system chosen as a reference point. This ratio is usually expressed in **decibels.**

TRANSMISSION LIMIT. A limiting wavelength or frequency above or below which a given type of radiation is practically all absorbed by a given medium. If the limits are sharply defined, the medium acts as a sharp cut-off **filter** for that radiation.

TRANSMISSION LINE. The conducting system for electrical energy between two or more points. In communication circuits, certain properties of the line become important. This is due to the much shorter wavelengths used in such circuits so the lines used will frequently be several wavelengths long. Thus at 60 cycles (commercial power **frequency**) a line would have to be a little over 3000 miles long to be a wavelength while in the middle of the audio range (5000 cycles) it would only need to be about 37 miles and at the ultra high radio frequencies only a few inches. If a line has a length of the order of a wavelength or more and is not matched (see **matching**) reflection and resultant standing waves will result. Often this is a serious drawback to its useful function but for high radio frequencies this property is used to great advantage. A line having standing waves appears at its input terminals to be a resonant circuit (alternately as a series and a parallel type) when adjusted to multiples of a quarter-wave in length. Since at the very high radio frequencies a quarter-wavelength line is only a few inches long, such lines are often used to serve as resonant circuits for **tanks in oscillators, amplifiers,** etc. Used in this connection they are superior to ordinary lumped inductance and capacitance circuits as they have a much higher **Q** and when properly constructed will cause much lower radiation losses. If these lines are adjusted in length to something other than quarter-wave multiples they act as inductance or capacitance, depending upon the exact length. Such lines are used for a variety of functions, e.g., **tanks,** radio-frequency **chokes,** tuning elements, coupling elements, etc. They are widely used at frequencies of a hundred or so megacycles and at still higher frequencies are the only satisfactory means for tuning and coupling circuits. In these applications the **coaxial line** or **wave guide** are ordinarily used since they do not radiate but at the lower frequencies parallel lines are sometimes used for convenience. Various short- and open-circuited lines are useful for impedance **matching** at **radio frequencies.** In power circuits the losses of the line, while important from an efficiency standpoint are not too serious but in telephone circuits these losses may be an appreciable part of the total power and consequently are a serious problem. Also a line which is long enough to be comparable to a wavelength will produce appreciable phase shift and this may cause trouble in communication circuits. Important constants of lines may be summed up in the following equations:

$$\gamma = \sqrt{zy} \qquad |I| = |I_s|e^{-\alpha l}$$

$$\gamma = \alpha + j\beta$$

$$Z_0 = \sqrt{z/y} \qquad I = I_s e^{-\gamma l}$$

where z is the series **impedance** of the line per unit length, y the shunt **admittance** per unit length, γ the **propagation constant,** α the **attenuation constant,** β the **wavelength or phase constant,** Z_0 the **characteristic impedance,** $|I|$ the magnitude, I the vector current

at a distance l from the sending end, I_s the sending end current, e the base of the natural logarithms. The phase shift along the line may be found from

$$\text{Phase} = \beta l.$$

(See also **balanced line; coaxial line; waveguide.**)

TRANSMISSION LINE, COAXIAL (CONCENTRIC). A **transmission line** consisting of two coaxial cylindrical conductors.

TRANSMISSION LINE, EXPONENTIAL. A two-conductor **transmission line** whose characteristic impedances vary exponentially with electrical length along the line.

TRANSMISSION LINE, RADIAL. A pair of parallel conducting planes used for propagating uniform, circular-cylindrical waves having their axes normal to the planes.

TRANSMISSION LINE, SHIELDED. A **transmission line** whose elements essentially confine propagated electrical energy to a finite space inside a conducting sheath.

TRANSMISSION LOSS. (1) The power lost in transmission between one point and another. It is measured as the difference between the net power passing the first point and the net power passing the second. (See **standing wave loss factor.**) In underwater sound, the transmission loss H is defined to be $H = S - L$, where S is the **sound level** in decibels, and L is the **sound pressure level** in decibels above rms pressure of 1 dyne/cm^2.

TRANSMISSION MODE. The various transmission modes in a **waveguide** are characterized by the electric and magnetic field patterns in a plane normal to the guide axis. When the magnetic vector is perpendicular to the direction of travel, the wave is *transverse magnetic*, or a TM-wave. When the electric vector is transverse, it is a *transverse electric*, or TE-wave. If both vectors are perpendicular to the direction of travel, the wave is *transverse electromagnetic*, or a TEM-wave. There are an infinite number of transmission modes in a guide, but each mode possesses a **cut-off frequency**; waves of lower frequency cannot be propagated by the corresponding mode. The lowest of these frequencies is the absolute cut-off frequency of the guide, and the corresponding mode is the dominant transmission mode. Note that a pair of parallel wires is a waveguide possessing a cut-off frequency of zero, i.e., direct current is propagated.

TRANSMISSION MODE, PRINCIPAL. The dominant **transmission mode** of a waveguide.

TRANSMISSION, MONOCHROME (BLACK AND WHITE). In television, the transmission of a signal wave which represents the **brightness** values in the picture, but not the **chromaticity** values.

TRANSMISSION (RECEPTION) MULTIPATH. The tracing of multiple paths by transmitted waves to reach a point of reception. The waves received may consist of the original wave plus wave components of the original which have been reflected from ionosphere layers surface of the earth, buildings, aircraft, etc.

TRANSMISSION, MULTIPLEX. The simultaneous transmission of two or more signals within a single channel. Multiplex transmission as applied to FM broadcast stations means the transmission of facsimile or other signals in addition to the regular broadcast signals.

TRANSMISSION, MULTIPLEX RADIO. The simultaneous transmission of two or more signals using a common **carrier wave.**

TRANSMISSION OF LIGHT (TRANSMITTANCE). The ratio of the light flux transmitted by a medium to the light flux incident upon it. Transmission may be either diffuse or specular.

TRANSMISSION PLANE. The **plane of vibration** of **polarized light** which will pass through a given **polarizer,** such as a **Nicol prism.**

TRANSMISSION, SEQUENTIAL COLOR. In television, the sending of the signals arising from differently-colored sections of an image one after the other, in a certain order. (See **television, color, dot-sequential; television, color, field-sequential;** and **television, color line-sequential.**)

TRANSMISSION, SERIAL. A system of **information** transmission in which the characters of a word are transmitted in sequence over a single line, as contrasted to **parallel transmission.**

TRANSMISSION, SINGLE - SIDEBAND. That method of signal transmission in which

one **sideband** is transmitted and the other sideband is suppressed. The carrier wave may be either transmitted or suppressed.

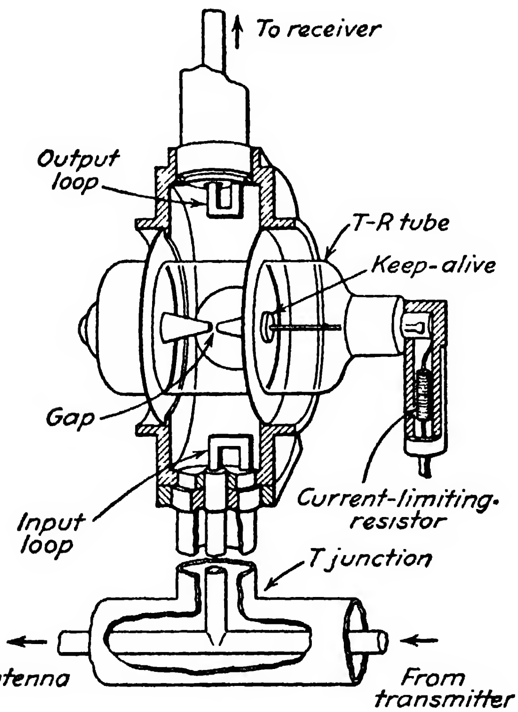
TRANSMISSION SYSTEM, ACOUSTIC. An assembly of elements adapted for the transmission of sound.

TRANSMISSION SYSTEM, MECHANICAL. An assembly of elements adapted for the transmission of mechanical power.

TRANSMISSION, VESTIGIAL-SIDEBAND. That method of signal transmission in which one normal sideband and the corresponding vestigial sideband (see **sideband, vestigial**) are utilized.

TRANSMISSIVITY. Ordinarily defined as the ratio of the transmitted radiation to the normally-incident radiation, as radiation is passed through a boundary between two media, or through a plate of one medium imbedded in another medium. Also expressed as per cent transmission by multiplying by 100.

TRANSMIT-RECEIVE SWITCH (T-R SWITCH) (T-R GAP) (T-R TUBE). An open spark gap or gas-filled tube used in a **duplexer.** At frequencies above 3000 Mc, the **gaps** are usually incorporated into **cavities** because of lower losses. In order to reduce the field strength required for **breakdown** of the T-R tube, the tube is provided with **a keep-alive electrode.** A typical assembly for coaxial lines is shown.



Typical T-R box (By permission from "Microwave Theory and Techniques" by Reich et al., Copyright 1953, D. Van Nostrand Co., Inc.)

TRANSMITTANCE. The ratio of the **radiant power** transmitted by a body to the total radiant power entrant to the body. Commonly, the body is in the form of a parallel-sided plate, and the radiation in the form of a parallel beam incident normally on the surface of the plate. Transmission measurements should be corrected for **reflection** and, in most cases, for **scattering.** Transmittance so corrected is sometimes called internal transmittance. If only the emergent radiation which is parallel to the entrant beam is observed, the transmittance is called specular. If all the emergent radiation is observed, the transmittance is called diffuse. The transmittance may be measured for any radiation, for visible light (optical transmittance), or as a function of the wavelength of the radiation (spectral transmittance).

TRANSMITTANCE, DIRECTIONAL LUMINOUS. The ratio of the **luminance** of the surface at which light leaves a diffusing object to the **illuminance** of the surface at which the light is incident upon the object; provided that (1) the luminance of the emergent surface is expressed in **lamberts** and the illuminance of the incident surface in lumens/sq cm, or (2) the luminance of the emergent surface is expressed in **foot-lamberts** and the illuminance of the incident surface in **foot-candles.**

TRANSMITTANCY. The ratio of the **transmittance** of a solution to that of the pure solvent in equivalent thickness.

TRANSMITTED WAVE. See **wave, transmitted.**

TRANSMITTER. (1) A device for converting sound waves into corresponding electrical oscillations, e.g., a **microphone** or **telephone** transmitter. (2) In radio communications, the complete group of equipment utilized in converting sound, or an **audio-frequency** electrical signal into the modulated **radio-frequency** signal fed to the **antenna.** The usage varies somewhat and may connote the modulators and radio-frequency **stages, or may**

be applied to more or less of the equipment constituting the complete broadcasting system.

TRANSMITTER, ALTERNATOR. A **transmitter** which utilizes power generated by a radio-frequency **alternator.**

TRANSMITTER, AMPLITUDE - MODULATED. A **transmitter** which transmits an amplitude-modulated (see **modulation, amplitude**) wave. In most amplitude-modulated transmitters, the frequency is stabilized.

TRANSMITTER, AMPLITUDE - MODULATED, AVERAGE POWER OUTPUT OF. The radio-frequency power delivered to the transmitter output terminals averaged over a **modulation** cycle.

TRANSMITTER, AURAL. The radio equipment used for the transmission of the aural (sound) signals from a television broadcast station.

TRANSMITTER, BROADCAST. A **transmitter** used for the commercial AM, FM and TV channels, singly or in combination

TRANSMITTER, CRYSTAL - CONTROLLED. A **transmitter** whose **carrier frequency** is directly controlled by the electromechanical characteristics of a piece of material of crystalline structure.

TRANSMITTER, CRYSTAL - STABILIZED. A **transmitter** employing **automatic frequency control,** in which the reference frequency is that of a **crystal oscillator.**

TRANSMITTER, DOUBLE-SIDEBAND. A **transmitter** which transmits the **carrier frequency** and both **sidebands** resulting from the **modulation** of the carrier by the modulating signal.

TRANSMITTER, FIXED. A **transmitter** that is operated in a fixed or permanent location.

TRANSMITTER, FIXED-FREQUENCY. A **transmitter** designed for operation on a single **carrier frequency.**

TRANSMITTER, FREQUENCY - MODULATED. A **transmitter** which transmits a frequency-modulated wave.

TRANSMITTER, MOBILE. A **transmitter** designed for installation in a vessel, vehicle, or aircraft, and normally operated while in motion.

TRANSMITTER, MULTICHANNEL RADIO. A **transmitter** having two or more complete radio-frequency portions capable of operating on different frequencies, either individually or simultaneously.

TRANSMITTER, MULTIFREQUENCY. A **transmitter** capable of operating on two or more selectable frequencies, one at a time, using preset adjustments of a single radio-frequency portion.

TRANSMITTER, PHASE - MODULATED. A **transmitter** which transmits a phase-modulated (see **modulation, phase**) wave.

TRANSMITTER, PORTABLE. Commonly used at present for "transportable transmitter" Preferred use of this term covers a **transmitter** which can be readily carried on a person and may or may not be operated while in motion. This includes the class of so-called "walkie-talkies," "handy-talkies," and "personal" transmitters.

TRANSMITTER, PULSE. A pulse-modulated **transmitter** whose peak power-output capabilities are usually large with respect to average power-output rating

TRANSMITTER PULSE DELAY. See **transducer pulse delay.**

TRANSMITTER, RADIO. See **transmitter** (2).

TRANSMITTER, SINGLE-SIDEBAND. A **transmitter** in which one **sideband** is transmitted and the other is effectively eliminated.

TRANSMITTER, SPARK. A **transmitter** which utilizes the **oscillatory discharge** of a **capacitor** through an **inductor** and a spark gap, as the source of its radio-frequency power.

TRANSMITTER, TRANSPORTABLE. A **transmitter** designed to be readily carried or transported from place to place, but which is not normally operated while in motion This has been commonly called a "portable" transmitter, but the term transportable transmitter is preferred.

TRANSMITTER, VACUUM-TUBE. A **transmitter** in which **electron tubes** are utilized to convert the applied electric power into radio-frequency power.

TRANSMITTER, VESTIGIAL-SIDEBAND. A **transmitter** in which one **sideband** and a portion of the other are intentionally transmitted. (See **sideband, vestigial.**)

TRANSMITTER, VISUAL. (1) All parts of a television transmitter which handle picture signals, whether exclusively or not (2) Sometimes, however, limited to the radio equipment for the transmission of visual signals only.

TRANSMITTING CURRENT RESPONSE. See **response, transmitting current.**

TRANSMITTING EFFICIENCY (PROJECTOR EFFICIENCY). Of an electroacoustic transducer (see **transducer, electroacoustic**) the ratio of the total acoustic power output to the electric power input. In computing the electric power input, it is customary to omit any electric power supplied for **polarization** or **bias.**

TRANSMITTING POWER RESPONSE (PROJECTOR POWER RESPONSE). See **response, transmitting power.**

TRANSMITTING VOLTAGE RESPONSE. See **response, transmitting voltage.**

TRANSMITTIVITY. The internal transmittance (see **transmittance**) for unit thickness of a non-diffusing substance

TRANSMUTATION. The conversion of one element into another.

TRANSPONDER. See **pulse repeater.**

TRANSPORT MEAN FREE PATH (NUCLEAR REACTORS). (1) Where the **Fick law** is applicable, three times the diffusion coefficient of **neutron flux.** (2) A modified mean free path used to correct for the persistence of velocities and anisotropy of **scattering.**

TRANSPORT NUMBER (OR TRANSFERENCE NUMBER). The transport number of a given **ion** in an **electrolyte** is the fraction of total current carried by that ion.

TRANSPORT NUMBER, METHODS FOR. See **sheared boundary method; moving boundary method; Hittorf method.**

TRANSPORT THEORY. A theory based on an approximation o the Boltzmann equation for such onditions that the **Fick law is not** applicable

TRANSPORTABLE TRANSMITTER. See **transmitter, transportable.**

TRANSPORTATION LAG (DELAY). Synonym for **dead-time lag.**

TRANSPOSE. See **matrix, transposed.**

TRANSPOSITION. A cyclic permutation of degree two. (See **permutation, cyclic.**)

TRANSRECTIFICATION. **Rectification** in one circuit as a result of an applied signal in another. An example is the **plate** or **anode bend detector.**

TRANSRECTIFICATION FACTOR. The quotient of the change in average current of an electrode by the change in the amplitude of the alternating sinusoidal voltage applied to another electrode, the direct voltages of this and other electrodes being maintained constant. Unless otherwise stated, the term refers to cases in which the alternating sinusoidal voltage is of infinitesimal magnitude

TRANSTRICTOR. A name which has been applied to a unipolar transistor (See **transistor, unipolar.**)

TRANSVERSE ELECTRIC WAVE (TE WAVE). See **wave, transverse electric (TE wave).**

TRANSVERSE ELECTROMAGNETIC WAVE (TEM WAVE). See **wave, transverse electromagnetic (TEM wave).**

TRANSVERSE MAGNETIC WAVE. See **wave, transverse magnetic (TM wave).**

TRANSVERSE ROD SUSCEPTANCE. See **tuner, screw.**

TRANSVERSE SEPTA (SEPTUM). Transverse **diaphragms** placed in **waveguides.**

TRANSVERSE WAVE. See **wave, transverse.**

TRANSURANIC ELEMENTS. Elements with atomic numbers higher than uranium, which has an atomic number of 92.

TRAP. (1) An absorption filter (see **filter, absorption**) used to trap or remove an undesired signal from a **receiver,** as in the **sound trap** used in the video amplifier of a television receiver to prevent the sound signal from interfering with the picture. (2) A device designed to reduce the effect of vapor pressure

of the mercury or oil in a **diffusion pump** on the high-vacuum side of the system.

TRAP, ALKALI-METAL MERCURY. A mercury-vapor trap (see **trap (2)**) consisting of a section of tubing lined internally with a substantial amount of sodium or potassium. The trapping action depends on the formation of an amalgam of very low vapor pressure.

TRAP, LOW-RESISTANCE. One of a variety of traps (see **trap (2)**) designed to have a low resistance to molecular flow, so that high pumping speed is maintained at the same time as high vacuum.

TRAP, REFRIGERATED. A trap (see **trap (2)**) which consists of a section of the vacuum line refrigerated to very low temperature, so that condensation of mercury or oil vapor takes place.

TRAPEZOIDAL RULE. A special case of the **Newton-Cotes formula** for **numerical integration**

$$\int_a^b f(x)dx$$

$$= h\left[\frac{y_0}{2} + y_1 + y_2 + \cdots + y_{n-1} + \frac{y_n}{2}\right]$$

where h is the interval between equally-spaced values of x, the independent variable

TRAPPING. An electron in the **conduction band** of a **semiconductor** or **insulator** may be caught by any irregularity in the crystal lattice and trapped there until it can be released by thermal agitation. The rate of release will depend on exp $(-E/kT)$ where E is the depth of the trap—hence a material containing large numbers of deep traps may show reduced **photoconductivity**, for example, and a slow decay as the electrons are released after the light has been removed.

TRAUBE RULE. A relationship between the effects upon the **surface tension** of water produced by the addition of organic substances in various **homologous series**. In dilute solutions, the effect of each additional $-CH_2-$ group in a given series is to decrease by three times the concentration at which equal lowering of surface tension is obtained.

TRAVELING PLANE WAVE. See **wave, traveling plane.**

TRAVELING-WAVE MAGNETRON OSCILLATIONS. See **magnetron oscillations, traveling-wave.**

TRAVELING WAVE TUBE. See **tube, traveling wave.**

TRAVELING WAVE TUBE, ELECTRON WAVE TYPE OF. See **tube, electron-wave.**

TREE. A set of connected **branches** including no **meshes.**

TRF. Abbreviation for tuned radio frequency.'

TRIANGLE. A **polygon** with three sides and three angles all lying in the same plane. From their properties, they are named as follows: **acute,** all interior angles acute, **congruent,** two or more triangles which may be superimposed, and which then become equal in all of their properties; **equal,** with equal areas but not necessarily congruent; **equiangular,** with three equal interior angles and therefore also **equilateral,** with three equal sides; **isosceles,** two sides are equal; **oblique,** containing no right angle; **obtuse,** containing one obtuse interior angle; **right,** one angle is $\pi/2$ (the opposite side is the **hypotenuse** and the other sides are the two **legs**); **scalene,** no sides are equal; **similar,** the angles are equal and the corresponding sides are proportional.

Given a sufficient number of parts of a triangle (sides and angles), the remaining parts may be found by trigonometric methods, a process called solving the triangle. For a right triangle, two parts must be given in addition to the right angle and one of these must be a side. For an oblique triangle, there are six parts, three each angles and sides. If three are given, including one side, the other three may be found.

TRIANGLE, SPHERICAL. A spherical triangle is a figure bounded by arcs of three great circles on a sphere. It is a **polygon** with three sides. The sum of its angles is greater than 180° but less than 540°. The difference between the sum of its angles and 180° is the **spherical excess.** If E is this excess and the triangle is cut from a sphere of radius R, the area of the spherical triangle is $S = \pi R^2E/180$. Such triangles are named according to their properties and may be solved by methods of spherical trigonometry, an extension of the methods of plane trigonometry.

TRIBO-ELECTRIFICATION. When two dissimilar substances are rubbed together, they become oppositely electrified; and if either is an insulator, it retains a charge. For example, if glass is rubbed with silk, the glass becomes positive and the silk negative Careful experiments make it appear probable that this is a type of **contact potential difference,** and that the friction serves only to bring about surface contact over a larger area

TRIBOLUMINESCENCE. **Luminescence** attributable to friction It occurs usually in crystalline substances

TRICHROISM. The property of exhibiting three different colors when viewed in as many different directions

TRICHROMATIC COEFFICIENTS. Three coefficients, based on the response of the standard eye to the spectral distribution of light from a standard source, which may be used to describe the **chromaticity** of a source

TRIGGER. To set off or initiate a certain action in an electrical circuit by the application of a pulse of voltage

TRIGGER ACTION. Synonym for **snap action.**

TRIGGER CIRCUIT. Many of the recent developments in the application of electron **tubes** have utilized various types of triggering action By this is meant a circuit which suddenly changes its electrical condition, just as if a trigger had tripped it (see **snap action**) While there are many varieties of such circuits, they represent some form of unstable electrical equilibrium so the triggering disturbance, whatever it may be, causes it to break over into a new condition These circuits range from very simple **thyratron** devices to elaborate vacuum-tube circuits which give some special type of output Many of the modern developments would be impossible without these devices

TRIGGERING. An instability which may occur in **self-saturating magnetic amplifiers** in the vicinity of cut-off.

TRIGONOMETRIC FUNCTION. If θ is one of the acute angles in a right-angle triangle, x is the side of the triangle nearest to θ, y the side opposite the angle, and r the **hypotenuse,** the trigonometric functions are

$$\sin\theta = y/r;\quad \cos\theta = x/r;\quad \tan\theta = y/x;$$

$$\csc\theta = 1/\sin\theta,\quad \sec\theta = 1/\cos\theta;$$

$$\cot\theta = 1/\tan\theta.$$

Other quantities, but not often used, are vers θ, covers θ, hav θ, exsec θ. (See also **inverse trigonometric function.**)

TRIMMER CAPACITOR. A small **capacitor** used to adjust a **tuned circuit** to the desired **resonance frequency.** Essential in **tracking** superheterodyne receivers

TRINOSCOPE. A color-television viewing arrangement consisting of three **kinescopes,** three **lenses,** and three **deflection yokes.**

TRIODE. A three-electrode **electron tube** containing an anode, a cathode, and a control electrode

TRIODE, CLOSE-SPACED. A **triode** with extremely small grid-cathode spacing (0 0006 in as an example) developed because of its superior **gain-bandwidth product.**

TRIODE, DOUBLE. See **duotriode.**

TRIODE, GAS. A triode gas tube (See **gas tube; thyratron;** starter-anode **glow tube.**)

TRIODE, PENCIL. See **tube, pencil.**

TRIP ACTION (INSTABILITY). Of a magnetic amplifier, an instability caused by **feedback.** It is said to occur when the **control characteristic** ceases to be single-valued

TRIPLE INDICATOR. In weather map analysis, a **discontinuity** or marked change in temperature, dew point and wind direction across a relatively narrow area on a synoptic chart constitutes a "triple indicator" of the existence of a frontal zone in that area

TRIPLE MOLECULAR COLLISION. A collision occurring when three molecules collide simultaneously, or come into contact for a short period of time The probability of occurrence is very small Sometimes postulated to explain certain phenomena, e.g., recombination of atoms in chemical kinetics.

TRIPLE POINT. The point in the **diagram of state** of a substance at which the three phases gas, liquid and solid are in equilibrium.

TRIPLE PRODUCT OF VECTORS. If **A**, **B**, **C** are three **vectors**, they may be combined to form products with meaning as follows: (1) $\mathbf{A}(\mathbf{B}\cdot\mathbf{C})$, a vector with the same direction as **A** and magnitude $ABC \cos \theta$, where θ is the angle between **B** and **C**. (2) $\mathbf{A}\cdot(\mathbf{B}\times\mathbf{C})$, the **scalar triple product**, giving the volume of a parallelepiped with edges **A**, **B**, **C**. It is frequently indicated by the symbol [**ABC**] and if the three vectors all lie in the same plane [**ABC**] = 0. It may be written in terms of its components as a **determinant**

$$[\mathbf{ABC}] = \begin{vmatrix} A_x & A_y & A_z \\ B_x & B_y & B_z \\ C_x & C_y & C_z \end{vmatrix}.$$

Its properties include

$$[\mathbf{ABC}] = [\mathbf{BCA}] = [\mathbf{CAB}] = -[\mathbf{ACB}]$$
$$= -[\mathbf{BAC}] = -[\mathbf{CBA}].$$

(3) The **vector triple product**, $\mathbf{V} = \mathbf{A}\times(\mathbf{B}\times\mathbf{C})$ is perpendicular to both **A** and the vector $\mathbf{B}\times\mathbf{C}$. It therefore lies in the plane determined by **B** and **C**. Its properties include: $\mathbf{A}\times(\mathbf{B}\times\mathbf{C}) = \mathbf{B}(\mathbf{A}\cdot\mathbf{C}) - \mathbf{C}(\mathbf{A}\cdot\mathbf{B}) = -\mathbf{A}\times(\mathbf{C}\times\mathbf{B}) = (\mathbf{C}\times\mathbf{B})\times\mathbf{A} = -(\mathbf{B}\times\mathbf{C})\times\mathbf{A}$.

TRISTIMULUS VALUES. Any sample of light can be matched by the mixture of three different standard stimuli. The magnitudes of the three stimuli needed to match a particular sample are called the tristimulus values of that sample. The standard stimuli must be specified. Those most commonly used are the **CIE** color mixture functions X, Y, Z, of which Y is the **luminosity function** (see *Science of Color*, pp. 254-316, Crowell (1953))

TRITIUM. The hydrogen isotope of mass 3.

TRITON. The nucleus of **tritium**, that is of hydrogen of mass number 3, particularly when it is used as a bombarding particle or is emitted as a result of a **nuclear reaction.**

TROCHOID. The path described by a point on a line drawn through the center of a circle as it rolls along a straight line. If the given line is the X-axis and the point is originally on the Y-axis, the curve is given by

$$x = a\theta - b\sin\theta; \quad y = a - b\cos\theta$$

where a is the radius of the circle, b the distance of the point from the center of the circle, and θ is the angle through which the circle has rolled. If $b = a$, the curve is called a **cycloid;** if $b < a$, the cycloid is **curtate** and if $b > a$, **prolate.**

TROCHOIDAL MASS ANALYZER. A **mass spectrometer** wherein the ion beams traverse trochoidal paths within electric and magnetic fields mutually perpendicular.

TROCHOTRON. A multi-electrode vacuum tube used for **scaling,** which operates by utilizing an electron beam in a magnetic field to charge elements in sequence.

TROLAND. A unit of retinal illuminance (see **illuminance, retinal**), being the visual stimulation resulting from an illuminance of 1 **candle**/sq m when the apparent area of the **entrance pupil** of the eye is 1 sq m.

TROLAND AND FLETCHER THEORIES. Theories of hearing which maintain that the sensation of **pitch** depends upon the time nature of the stimulation. In addition the Fletcher theory emphasizes the importance of the position of excitation on the **basilar membrane.**

TROPOPAUSE. The discontinuity surface separating the **stratosphere** from the **troposphere.** It varies in height from about 55,000 ft at the equator to 25,000 ft over the poles.

TROPOSPHERE. That part of the earth's atmosphere in which temperature generally decreases with altitude, clouds form, and convection is active. The troposphere occupies the space above the earth's surface up to the **tropopause.**

TROPOSPHERIC WAVE. A **radio wave** that is propagated by reflection from a place of abrupt change in the **dielectric constant** or its gradient in the troposphere. In some cases the ground wave may be so altered that new components appear to arise from reflections in regions of rapidly changing dielectric constants; when these components are distinguishable from the other components, they are called tropospheric waves.

TROPOTRON. One form of **magnetron.**

TROUBLE-LOCATION PROBLEM. In computer terminology, a test problem whose incorrect solution supplies information on the location of faulty equipment; used after a check problem has shown that a fault exists.

TROUGH LINE. A line drawn in a pressure field along which the **isobars** are symmetrical and curved cyclonically. A V-shaped trough normally contains a **front;** a U-shaped trough generally contains no front or a very weak one. Usually there is considerable weather associated with a trough line of the V-variety. Trough line movements can be computed and a forecast made of future positions.

TROUTON RULE. The ratio of the molar **latent heat of evaporation** of a liquid to its boiling point on the absolute scale is a constant, approximately 23 calories/deg. This rule applies only in a limited number of cases. Compounds which associate, such as alcohol, do not obey this law. Deviations are also observed with materials of low boiling points and low molecular weights, and with substances of high boiling points.

TROY SYSTEM. A system of weights and measures in which the ounce is identical with that in the **apothecaries' system.**

Troy System

24 grains = 1 pennyweight
20 pennyweights = 1 ounce
12 ounces = 1 pound
1 pound (Troy) = 373.25 grams
1 pound (Troy) = 0.823 pounds (avoirdupois)

TRUNCATION ERROR. In computer terminology, error resulting from the approximation of operations in the infinitesimal calculus by operations in the calculus of finite differences.

TRUSS. An assemblage of solid bodies in the form of rods, bars, etc., so combined as to form a rigid framework in which the length of each section can be changed by deforming forces only.

TSCHEBYSCHEFF EQUATION. A special case of the **Gauss hypergeometric differential equation**

$$(1 - z^2)y'' - zy' + n^2y = 0,$$

where n is an integer. Its general solution is a linear combination of the two kinds of **Tschebyscheff polynomials.** (The name is often spelled differently, particularly Tchebycheff.)

TSCHEBYSCHEFF POLYNOMIAL. A solution of the **Tschebyscheff differential equation.** The two linearly independent solutions are known as **polynomials** of the first and second kind. Those of the first kind, which are the more familiar ones, may be represented by the **hypergeometric series**

$$T_n(z) = F\left(n, -n, \frac{1}{2}; \frac{(1 - z)}{2}\right).$$

Other definitions of them are:

$$T_n(z) = \cos(n \cos^{-1} z);$$

$$T_n(z) = z^n - \binom{n}{2} z^{n-2}(1 - z^2) + \binom{n}{4} z^{n-4}(1 - z^2)^2 \mp \cdots;$$

$$T_n(z) = \frac{(-1)^n \sqrt{(1 - z^2)}}{1 \cdot 3 \cdot 5 \cdots (2n - 1)} \frac{d^n}{dz^n} (1 - z^2)^{n - \frac{1}{2}},$$

See also **generating function.** The polynomials are **orthogonal:**

$$\int_{-1}^{1} \frac{T_m(z)T_n(z)}{\sqrt{1 - z^2}} dz = I_{mn},$$

where $I_{mn} = 0$, $m \neq n$, $I_{mm} = \pi/2$, $I_{00} = \pi$. Similar definitions and properties may be given for polynomials of the second kind.

TUBE. The word "tube," when used in this book without qualification, refers to an electron tube. (See **tube, electron.**)

TUBE, ACORN. A tube (see **tube, electron**) having small electrodes of essentially conventional shape which has an upper frequency limit of approximately 1200 mc. Its name comes from the fact that its shape and size is approximately that of an acorn.

TUBE ADMITTANCE, INPUT. See **electrode admittance.**

TUBE, ADMITTANCE, OUTPUT. See **electrode admittance.**

TUBE, AMPLIFICATION FACTOR OF. See **amplification factor.**

TUBE, BALLAST. A resistance element sealed in a tube, usually in a hydrogen atmosphere, used as a series component of a circuit to maintain the current constant. This is accomplished by designing the ballast tube so the resistance increases and decreases rapidly

with corresponding changes of current through it.

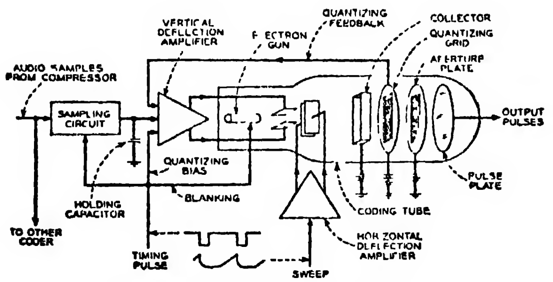
TUBE, BEAM-DEFLECTION. An electron-beam tube (see **tube, electron-beam**) in which current in an output circuit is controlled by transverse movement of the electron beam.

TUBE, BEAM-POWER. An electron-beam tube (see **tube, electron-beam**) in which use is made of directed **electron beams** to contribute substantially to its power-handling capability, and in which the **control grid** and the **screen grid** are essentially aligned.

TUBE, CAMERA (PICKUP TUBE). An electron-beam tube (see **tube, electron-beam**) in which an electron-current or charge-density image is formed from an optical image and is scanned in a predetermined sequence to provide an electrical signal.

TUBE, CATHODE-RAY. An electron-beam tube (see **tube, electron-beam**) in which the beam can be focused to a small cross-section on a surface, and varied in position and intensity to produce a visible pattern. (For more detailed discussion, see **cathode ray tube.**)

TUBE, CODING. An electron-beam tube (see **tube, electron-beam**) that transforms



Functional diagram of the coder (By permission from "Modulation Theory" by Black, Copyright 1953, D Van Nostrand Co, Inc)

speech samples into patterns of code characters.

TUBE COEFFICIENTS. The constants that describe the parameters of a **tube.** (See, for example, **transconductance, amplification factor,** and **plate resistance.**)

TUBE, COLD-CATHODE. An electron tube (see **tube, electron**) in which the cathode emission does not arise from **thermionic emission,** but from field, secondary, or **photoelectric emission.**

TUBE, CONVERTER. An electron tube (see **tube, electron**) that combines the **mixer and local-oscillator** functions of a heterodyne-conversion **transducer.**

TUBE CORONA. See **corona, tube.**

TUBE, CROOKES. A tube used in the investigation of the phenomena associated with the conduction of electricity through gases at low pressures; especially the study of the emission by the cathode of radiations which were, therefore, called **cathode rays,** and were found to be streams of electrons. Later the positive rays, i.e., streams of positively charged ions, were found to be produced in modified tubes of this type.

TUBE COUNT. A terminated discharge produced by an **ionizing event** in a radiation **counter tube.**

TUBE, COUNTER. See entries under **counter tube.**

TUBE, DIODE. An electron-tube diode. (See **tube, electron;** also **diode.**)

TUBE, DISCHARGE. (1) A **tube** used to discharge the stored energy as desired. For example, the tube which periodically shorts or discharges a capacitor being charged from a constant-current source, the objective being, in this case, the sawtooth voltage developed by the capacitor. (2) Any tube containing gas or vapor at low pressure and having two or more electrodes, through which energy may be supplied to maintain a gaseous discharge. (See **discharge, gaseous.**)

TUBE, DISK-SEALED. A **tube** designed with low interelectrode spacings, and low electrode-lead inductances for use at ultra-high frequencies. Connections to the electrodes are made through disks sealed in the tube's envelope. The disks in turn are usually fitted into **resonant cavities** designed to receive them.

TUBE, DISSECTOR. A camera tube (see **tube, camera**) having a continuous **photocathode** on which is formed a photoelectric emission-pattern which is scanned by moving its electron-optical image over an **aperture.**

TUBE, DOOR-KNOB. A vacuum **tube** especially built for **ultra high frequency** use where the lead inductance and the capacitance between electrodes of the conventional tubes prevent their use. The door-knob tube gets its name from its resemblance to a door knob, the peculiar shape being the result of an effort to get the leads as short as possible and have a minimum amount of dielectric material in the construction. These tubes do not have a conventional base, the leads being brought out directly through the glass and made heavy enough to serve as connections.

TUBE, ELECTROMETER. A high-vacuum **tube** having a very low control-electrode conductance to facilitate the measurement of extremely small direct current or voltage. (See entries under **electrometer.**)

TUBE, ELECTRON. An electron device in which conduction by electrons takes place through a vacuum or gaseous medium within a gas-tight envelope. The electron tubes form the heart of many of the modern developments in communication and industry. It is safe to say that without them we would have no **radio, television,** satisfactory long-distance telephone service, and many of our common every-day necessities could not be produced as cheaply and as well without the tubes. The electron tube is a device in which **electrons** are freed from the restraints of a solid conductor, pass across a free space (vacuum or gas at low pressure) and are again collected by a solid conductor, but during this passage in free space are controlled in manners which would be impossible if they had not been temporarily freed. Thus we may control the flow of current magnitude in a wire by controlling the voltage across its terminals, but when the electrons are passing between the electrodes of a tube we can superimpose many kinds of complicated controls if desired.

Tubes may be classified in various ways and no one way gives a complete picture. As a first general classification we might use vacuum and gas-filled, the first being a tube which has been as highly evacuated as possible and the latter being one which has been evacuated and then partially refilled with a gas at low pressure. The characteristics of the two groups are usually quite different. Then they may be classified according to the number of elements, two-electrode tubes being diodes (the simplest electron tube must have at least two electrodes), three-electrode tubes being **triodes,** four being tetrodes, five being pentodes and so on. To give anything approaching a satisfactory picture of the tube it is necessary to use both types of classification and this is usually done.

Let us examine the vacuum-tube family first, starting with the simple diode. This has a thermionic cathode which may be directly (filament type) or indirectly heated to produce electron emission. The other electrode is the anode which collects the electrons. Since electrons are negative charges they are attracted by positive-charged electrodes and repelled by negatively charged ones. Thus if the anode is made positive with respect to the cathode the emitted electrons will be attracted to it, the current usually varying as the $\frac{3}{2}$ power of the applied voltage. If the anode is negative it repels the electrons and no current flows from one electrode to the other since the electrons are the carriers of the charge. It should be noted that the direction of the electron flow is opposite the conventional current direction. We can see, then, that if an alternating voltage is impressed across a diode current will flow only during the part of the cycle in which the anode is positive, thus giving rectifier action. This is the major use of this tube.

If a third electrode is inserted in the form of a grid between the **cathode** and **anode** its potential will also affect the electron flow across the tube. As this new electrode, the grid, is much closer to the cathode than the anode is, a given voltage on it will have much more effect on the electrons than the same voltage would if impressed on the plate. This is the basis of the amplifying action of all the grid-controlled tubes and the amplification factor of the tube is a measure of this relative effectiveness, varying from two or three to approximately a hundred in triodes and much higher for tetrodes and pentodes. The electrons which are controlled by the voltage on the grid pass on through the open grid structure and go to the plate (when it is positive as it normally is), thus giving the grid control over the plate current. Another advantage of this control is that the grid takes little or no power from the controlling circuit, yet the controlled power in the plate circuit may be quite large (there is no creation of energy involved since the additional power

comes from the direct current operating source).

The triode has undesirably high capacity between the anode and grid so a second grid may be put between these two electrodes to shield them electrostatically from one another. This gives the screen grid or tetrode tube. The screen grid is operated at a positive potential and ordinarily serves no purpose except shielding although in certain applications it is used for other effects. This tube is characterized by a high **amplification factor,** often many hundred, and a high dynamic **plate resistance,** running well over a megohm in some cases. Its big disadvantage is a **secondary emission** effect when the plate potential is lower than that of the screen. This is overcome in the pentode by inserting a third grid, the suppressor, between the screen grid and the plate, the suppressor being connected to the cathode. This new grid effectively suppresses secondary emission and at the same time the tube retains the desirable characteristics of the tetrode Another method of accomplishing the same result is the beam tube which is often used for power **amplifiers.** In this tube the electron stream across the tube is focused in such a way that it serves as its own suppressor.

Certain special-purpose vacuum tubes have still other electrodes, the pentagrid converter tube, for example, has five grids which are utilized to make the tube serve both as the **oscillator** and mixer tube of a superheterodyne **receiver.** Other multigrid tubes are used for mixing two or more signals to give a combined effect in the output. Other tubes have effectively two distinct tubes within the same envelope, e.g., a diode or duodiode and triode or pentode are often in the same envelope to serve as **detector** and first audio **amplifier** of a receiver.

The vacuum-tube family ranges from extremely small tubes used for **ultra high frequency** work to the giants of many kilowatt capacity used in radio **transmitters** and large industrial applications. Many of these larger sizes are water-cooled to dissipate the large amount of heat generated by the losses in the tube. The diodes are often called kenotrons and the grid-controlled tubes pliotrons, particularly in industrial applications.

The second group of tubes, the gas-filled, have in general quite different characteristics due to the ionization of the gas during operation. The diode is used primarily as a rectifier and is similar in general construction to the vacuum diode. It is possible to have a cold cathode in a gas-filled tube and in some low power applications such a cathode is often used. Besides the passage of electrons as in the kenotrons, the ionized gas gives positive ions as additional current carriers. The passage of the original electrons across the tube will produce ionization by collision with the gas molecules if the voltage applied across the tube is sufficient to give the electrons the necessary velocity. This ionization gives rise to more electrons and the positive ions. the latter being attracted to the negative cathode where they neutralize the space charge sheath around the cathode. The result of this is a greatly lowered tube voltage drop with the tube current going up tremendously and no longer following the $^3\!/_2$ power law. In fact, if the current is not limited by external **resistance** it reaches destructive values in a small fraction of a second. Hence gas-filled tubes must always be used in circuits with enough resistance to limit the current to safe values. Gas-filled diodes are widely used for rectifiers where large currents are desired since the drop across the tube is low and consequently the efficiency is high. The usual hot cathode tube has a drop between 8 and 15 volts. The **mercury pool tube** is a special type of gas-filled diode. The hot cathode tubes are often called phanotrons.

If the grid is inserted between the cathode and anode of a gas-filled tube the effect is decidedly different from the vacuum tube. At low grid voltages the tube behaves as a vacuum tube, but as the grid voltage is raised, the gas suddenly breaks into a discharge, the voltage drop falling to a low value and the current increasing to a high value. Thus a voltage on the grid can trigger a large current in the plate circuit. This grid-controlled, hot cathode, gas-filled tube is the thyratron. The behavior of the thyratron can be forecast from its grid control characteristic curve, which shows the relation between the grid voltage and the anode voltage for breakdown of the gas. Thus for any given anode voltage the critical grid voltage to cause the tube to trigger may be obtained. Once that tube has broken down the grid no longer has control. For the grid to regain control it is necessary for the plate voltage to fall below the tube drop value and remain below this long enough

for the gas ions to recombine. This deionization time puts a definite limit to the frequency with which the tube can be triggered and controlled. On a-c the anode voltage falls every cycle and if the cycle lasts long enough the tube will not start on the next positive half-cycle unless the grid voltage exceeds the critical value. Thus while the control is not continuous as it is in vacuum tubes, it is possible to control within one cycle, which is sufficient for many applications While it has limited use in communication work it is very valuable for industrial control where a minute actuating power may control, through the thyratron, kilowatts of power in the plate circuit. For many industrial applications the triggering effect is exactly what is desired, the operation being equivalent to a switch without any arcing contacts, mechanical time lag etc By using special circuits, such as the **phase shift control,** various special effects may be obtained with the thyratron Many of these tubes have other grids for producing the desired characteristics. The **ignitron** is another type of controlled gas-filled tube The grid-glow tube is a cold cathode tube similar to the thyratron

Besides the tubes discussed here the **phototube** is also an electron tube

TUBE, ELECTRON-BEAM. An electron tube, the performance of which depends upon the formation and control of one or more **electron-beams.**

TUBE, ELECTRON-RAY. See **tuning indicator; tube, indicator.**

TUBE, ELECTRON-WAVE. A microwave **tube** which depends for its characteristics upon interaction of electrons, which are in a beam of initially-uniform **charge density,** but which have different individual average velocities, and have superimposed upon their average velocities a sinusoidal fluctuation, to generate an "electron-wave." The electron-wave is essentially a **convection current** that consists of a beam of uniform charge distribution upon which is superimposed a propagated sinusoidal fluctuation. When the electron-wave is passed through a suitable output device, the kinetic energy of the electrons in the wave is converted to radio-frequency energy that is available at the output terminals.

TUBE, GAS. See **gas tube** and **tube, electron.**

TUBE, GLOW-DISCHARGE, COLD-CATHODE. A **gas tube** that depends for its operation on the properties of a **glow discharge.**

TUBE, GRID CURRENT. See **electrode current; grid emission, secondary; grid emission, thermionic; gas current.**

TUBE, GRID-GLOW. A glow-discharge, cold-cathode tube (see **tube, glow-discharge, cold-cathode**) with a grid or starter anode which may be used to initiate anode current flow. Sometimes referred to as a cold-cathode gas triode.

TUBE, GROUNDED-GRID. A tube used in a grounded-grid amplifier. (See **amplifier, grounded-grid**)

TUBE, HEATED-CATHODE. See **tube, hot cathode.**

TUBE, HOT-CATHODE. An electron tube (see **tube, electron**) containing a hot cathode (See **cathode, hot.**)

TUBE, HOT-CATHODE, HEATER-TYPE. A hot-cathode tube employing an indirectly-heated cathode (See **cathode, indirectly-heated;** also **heater.**)

TUBE, INDICATOR. An electron-beam tube (see **tube, electron-beam**) in which useful information is conveyed by the variation in cross section of the beam at a luminescent target. Indicator tubes are sometimes used as **tuning indicators.**

TUBE, INDUCTION-OUTPUT. A **tube** in which the output electrode receives its energy from the electron stream by **induction** rather than collection.

TUBE, IONIC-HEATED CATHODE. An electron tube (see **tube, electron**) containing a **cathode** heated by the bombardment of positive ions.

TUBE, LIGHTHOUSE. A form of disk-sealed tube used as an UHF oscillator and amplifier. (See **tube, disk-sealed.**)

TUBE, LOCAL OSCILLATOR. An electron tube (see **tube, electron**) in a **heterodyne conversion transducer** to provide the local heterodyning frequency for a **mixer tube.**

TUBE "MAGIC-EYE." An indicator tube. (See **tube, indicator; tuning devices.**)

TUBE, MAGNETIC CRO. A **cathode-ray tube** with magnetic deflection and focusing.

TUBE, MERCURY-VAPOR. A **gas tube** in which the active gas is mercury vapor.

TUBE, MIXER. An electron tube (see **tube, electron**) that performs only the frequency-conversion function of a **heterodyne conversion transducer** when it is supplied with voltage or power from an external **oscillator.**

TUBE, MULTIELECTRODE. An electron tube (see **tube, electron**) containing more than three electrodes associated with a single electron-stream.

TUBE, MULTIPLE-UNIT. An electron tube (see **tube, electron**) containing within one envelope two or more groups of electrodes associated with independent electron streams. A multiple-unit tube may be so indicated; for example, duodiode, duotriode, diode-pentode, duodiode-triode, duodiode-pentode, and triode-pentode.

TUBE, PENCIL. A type of disk-seal tube made in the shape of a pencil. (See **tube, disk-seal.**)

TUBE, PERVEANCE OF. See **perveance.**

TUBE, PICTURE. A **cathode-ray tube** used to produce an image by variation of the beam intensity as the beam scans a **raster.** (See also **kinoscope.**)

TUBE, PHASITRON. See **phasitron tube.**

TUBE, PHOTOELECTRIC. See **phototube.**

TUBE, PLANAR-ELECTRODE. A **tube** in which the electrodes lie in parallel planes.

TUBE, PLATE RESISTANCE OF. See **plate resistance.**

TUBE, POWER-AMPLIFIER. A tube designed for the purpose of producing relatively large power output and power **gain.** (See **amplifier, power.**)

TUBE, REMOTE CUT-OFF. See **tube, variable-mu.**

TUBE, SHARP CUT-OFF. A **tube** which has a reasonably-constant **amplification factor** down to small values of plate current, as contrasted to the remote cut-off tube. (See **tube, remote cut-off.**)

TUBE, SQUIRREL-CAGE GRID. An early **velocity-modulation** tube whose grid resembled a squirrel cage.

TUBE, SOFT. A **tube** which has not been completely evacuated, or a vacuum tube (see **tube, vacuum**) which has lost part of its vacuum due to gas released from the electrodes and envelope.

TUBE, SPACE-CHARGE. A **tube** in which **space charge** is present to the extent that it affects the characteristics of the tube.

TUBE, STATIC CHARACTERISTIC OF A. The families of curves or graphs which represent the steady state volt-ampere characteristics of an electron tube (see **tube, electron**).

TUBE, TETRODE. See **tetrode.**

TUBE, THERMIONIC. An electron tube (see **tube, electron**) in which one of the electrodes is heated for the purpose of causing electron or ion emission from that electrode.

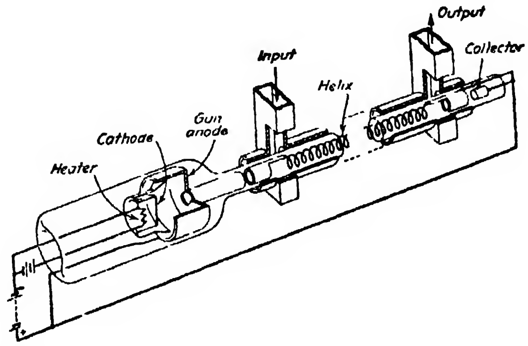
TUBE, THYRATRON. See **thyratron.**

TUBE, TRANSCONDUCTANCE OR MUTUAL CONDUCTANCE OF. See **transconductance.**

TUBE, TRANSIT ANGLE OF. See **transit angle.**

TUBE, TRANSIT TIME OF. See **transit time.**

TUBE, TRAVELING-WAVE. A broad-band, microwave tube which depends for its characteristics upon the interaction between the field of a wave propagated along a **waveguide** and a beam of electrons traveling with the wave. In this tube, the electrons in the beam travel with velocities slightly greater than that of the wave, and on the average are slowed down by the field of the wave.

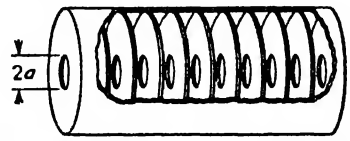


Schematic diagram of the traveling-wave amplifier (By permission from "Microwave Theory and Techniques" by Reich et al, Copyright 1953. D. Van Nostrand Co., Inc.)

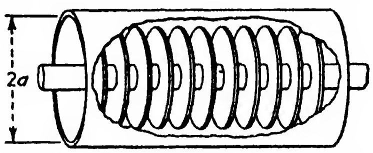
The loss in kinetic energy of the electrons appears as increased energy conveyed by the field of the wave. The traveling-wave tube may, therefore, be used as an **amplifier** or as an **oscillator.** In addition to the type of tube shown here the magnetron may function as a traveling wave tube (See **magnetron, traveling-wave.**)

TUBE, TRAVELING-WAVE, BACKWARD-WAVE. A traveling-wave tube in which the electrons travel in a direction opposite to that in which the wave is propagated.

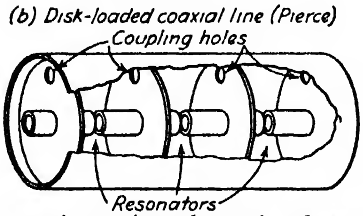
TUBE(S), TRAVELING-WAVE, CIRCUITS USED IN. In addition to the helix (**tube, traveling-wave**), other devices may be used to provide the correct wave propagation characteristics. Among these are:



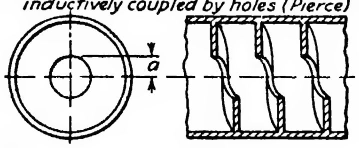
(a) Apertured - disk waveguide circuit (Pierce)



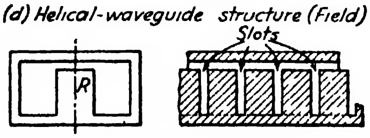
(b) Disk-loaded coaxial line (Pierce)



(c) A circuit consisting of a number of resonators inductively coupled by holes (Pierce)



(d) Helical-waveguide structure (Field)



(e) A circuit consisting of a ridged waveguide with transverse slots or resonators in the ridge (Field)

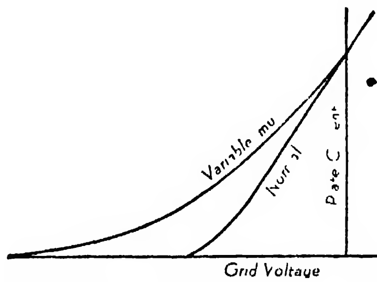
Some slow wave circuits for use in traveling-wave tubes (By permission from "Traveling-Wave Tubes" By Pierce, Copyright 1950, D Van Nostrand Co, Inc., and "Some Slow-Wave Structures for Traveling-Wave Tubes" by Field, *Proc I.R.E.* **37,** 34–40 (1949))

TUBE, TRAVELING-WAVE, MILLMAN. A traveling-wave tube which employs a **waveguide** loaded by means of a transversely-slotted ridge for its interaction space.

TUBE, TRIODE. See **triode.**

TUBE, VACUUM. An electron tube (see **tube, electron**) evacuated to such a degree that its electrical characteristics are essentially unaffected by the presence of residual gas or vapor.

TUBE, VARIABLE MU. An electron tube (see **tube, electron**) in which the amplification factor varies in a predetermined way with control-grid voltage To accomplish this the spacing of the grid wires is not constant but varies regularly along the grid. The result is that the mutual conductance characteristic of the tube approaches the grid-voltage axis very gradually rather than abruptly as in tubes of other types The figure shows the characteristics of both conven-



tional and variable mu tubes Since the slope of this curve is the mutual conductance of the tube, it will be apparent at once that the mutual conductance of the variable mu tube may be varied over a wide range by varying the operating bias of the tube This property is utilized in all standard **automatic volume control** circuits, the gain of the tube being controlled by the bias voltage which is obtained from the rectified **carrier.** (See **tube, remote cut-off.**)

TUBE, VELOCITY VARIATION. A **velocity-modulation** tube.

TUBE, VOLTAGE-AMPLIFIER. A **tube** designed to produce voltage gains associated with comparatively little available output power.

TUBE VOLTAGE DROP. The anode voltage during the conducting period.

TUBE, VOLTAGE GAIN. See **amplification, voltage (transducer); amplifier.**

TUBE, VOLTAGE REGULATOR. See **regulator tube.**

TUNABLE DIAPHRAGM. A microphone receiver with a **resonant frequency** alterable over a considerable range. The alteration is obtained by varying the air pressure in the microphone chamber, thus altering the tension in the diaphragm.

TUNED-GRID OSCILLATOR. See **oscillator, tuned-grid.**

TUNED-GRID, TUNED-PLATE OSCILLATOR. See **oscillator, tuned-grid, tuned-plate.**

TUNED-PLATE OSCILLATOR. See **oscillator, tuned-plate.**

TUNED RADIO FREQUENCY. A type of amplifier circuit which uses resonant circuits in the grid and/or plate circuits. As commonly used it denotes a type of **receiver** other than a superheterodyne which has one or more such stages preceding the **detector,** the condenser or inductance of the resonant circuit being varied to select the particular station desired. (See also **receiver.**)

TUNER, E-H. See **E-H tuner.**

TUNER, SLUG. See **slug tuner.**

TUNER, WAVEGUIDE. See **waveguide tuner.**

TUNGAR RECTIFIER. Trade name for a tube similar to a **rectigon.**

TUNING, DOUBLE-SPOT. The reception of a given station by a **superheterodyne receiver** at two different dial settings corresponding to two local **oscillator-frequencies.** One setting corresponds to the sum of the given frequency and the local oscillator, while the other reception point is due to the difference frequency.

TUNING FORK. A convenient device for preserving a comparatively pure harmonic vibration frequency at nearly constant value. It is a U-shaped bar of elastic material, usually steel (but in some modern forks, of fused quartz), the prongs of which vibrate alternately toward and away from each other with two nodes near the bend of the U. The fork may be set vibrating by striking one prong with a mallet, and will, after a moment to allow some high overtones to die out, emit a nearly pure musical tone. Large forks are often made to be driven electrically, like an electric bell or buzzer, and will then vibrate continuously for an indefinite time. Tuning forks are used in many experiments on musical sounds, as standards of pitch and also for the control of electric oscillations and electric timing devices.

TUNING INDICATOR. In radio circuits with **automatic gain control** the output is held constant for an appreciable amount of mistuning of the circuits. Thus the loudness of the output is not a satisfactory indication of when the set is correctly tuned. To remedy this various types of tuning indicators are used. These respond to the carrier amplitude and hence are not affected by the agc Formerly various instruments were used for this purpose, but now instruments are used only in communications receivers while ordinary home receivers use a special vacuum tube. This tube, often called a magic eye, has a willemite-coated cone-shaped plate upon which the electrons impinge, causing the coating to fluoresce. By connecting the **grid** so the carrier magnitude can control the number or pattern of the electrons hitting this coating, it can be used to indicate relative carrier strength. In any tuning, the correct setting for a given station is that which makes the carrier amplitude maximum

TUNING PROBE. An essentially lossless probe of adjustable penetration extending through the wall of the **waveguide, cavity resonator** or slotted **coaxial line.**

TUNING SCREW. A screw inserted into the top or bottom of a **waveguide** (parallel to the E-field) to develop **susceptance,** the magnitude and sign of which is controlled by the depth of penetration of the screw. One screw, variable in position along the guide, or two or three fixed-position screws, are required in most matching or tuning situations. Screw tuning is analogous to **stub-tuning in coaxial** systems

TUNGSTEN (WOLFRAM). Metallic element. Symbol W. Atomic number 74.

TUNNEL EXPERIMENT (VELOCITY OF LIGHT). See **Michelson rotating mirror.**

TUNNELING. See **penetration probability.**

TURBIDIMETER. An instrument which measures the reduction in **transmission** of light that is caused by interposing a solution containing solid particles between the light source and the eye. By using a known volume of solution in comparison with a standard, this instrument makes it possible to determine the mass effect, attributable to the number and size of the particles in the solution, and thus the quantitative amount of material present.

TURBIDIMETRY. The methods of analysis and measurement made by means of the **turbidimeter.**

TURBIDITY. The cloudiness in a liquid caused by the presence of finely-divided, suspended material.

TURBULENCE. An irregular eddying motion characteristic of fluid motion at high **Reynolds numbers.** The irregular eddying acts to transport fluid in bulk from one part of the flow to another, and is consequently an extremely effective agent for the transport of momentum, heat and matter.

TURN-OVER. See **voltmeter, electronic, peak-reading.**

TURNSTILE ANTENNA. See **antenna, turnstile.**

TURNTABLE RUMBLE. Low-frequency vibration mechanically transmitted to the recording or reproducing turntable and superimposed on the reproduction.

TURNTABLE WOW. See **wow.**

TWEETER. A high-frequency **loudspeaker** used in high fidelity apparatus, often in conjunction with a **cross-over network** and a **woofer.**

TWIN, ANNEALING. A structure occurring in several **face-centered** cubic metals after recrystallization. The (111) planes go in the sequence $CBACBA\cdots$ instead of $ABCABC\cdots$ as in the rest of the crystal. (See **close packed structure**.)

TWIN BOUNDARY DIFFUSION. A source of **internal friction** in solids due to the displacement of the boundary between **twinned crystallites.**

TWIN CRYSTALS. Those **crystals** in which one or more parts regularly arranged are in reverse position with reference to the other part or parts. They often appear externally to consist of two or more crystals symmetrically united, and sometimes have the form of a cross or star.

TWIN LINE. Colloquialism for a parallel-wire **transmission line.**

TWIN LEAD. See **twin line.**

TWINNING. (1) A process in which a region in a crystal assumes an orientation which is symmetrically related to the basic orientation of the crystal. Usually, layers of atoms within this region are translated with respect to a basic plane (the twinning plane). Each atomic plane is displaced by a distance which is proportional to its distance from the twinning plane. Bands of metal (twin bands) thus assume a **lattice structure** which is the mirror image of the unchanged portion of the lattice. (2) A fault condition in a television system with **interlace,** whereby the lines in alternate fields are not equally spaced, but tend to fall on top of one another, causing a loss of definition. (Also called **line pairing.**)

TWO-BODY FORCE. Type of interaction between two particles which is unmodified by the presence of other particles, e.g., Coulomb force between an electron and a proton. (Compare **many-body force.**)

TWO-BODY PROBLEM. The so-called two-body problem is the foundation of **celestial mechanics.** The solution of the problem requires two fundamental assumptions: (1) that two and only two objects exist in the universe, and (2) that some law of force between the two objects is given. With these assumptions admitted, the two-body problem may briefly be stated as follows: given the relative positions of two objects at any instant, together with their motions and masses at that instant, to predict the positions and motions of the objects at any subsequent instant.

TWO-FLUID MANOMETER. See **manometer, two-fluid.**

TWO-POSITION ACTION. That action in which a final control element is moved from one of two fixed positions in an **automatic controller** to the other.

TWO-SOURCE FREQUENCY KEYING. See **keying, two-source frequency.**

TWO-TONE KEYING. See **keying, two-tone.**

TWYMAN - GREEN INTERFEROMETER. An **interferometer** in which the initial parallel beam is divided by a half-silverized mirror, one-half reflected through a lens to an observing pinhole, while the other half is passed twice through a prism, lens, or block of glass before being reflected to the same pinhole. Used for testing the quality of optical materials and the flatness of surfaces.

TYNDALL EFFECT. A phenomenon first noticed by Faraday (1857). When a powerful beam of light is sent through a **colloidal solution** of high **dispersity,** the sol appears fluorescent and the light is polarized, the amount of polarization depending upon the size of the particles of the colloid. The polarization is complete, if the particles are much smaller than the wavelength of the radiation. (See also **scattering.**)

U

U. (1) Unit (u). (2) Overall coefficient of heat transfer (U). (3) Density of radiant energy (u). (4) Total internal energy (U), internal energy per atom or molecule (u or u_m), internal energy per unit mass (u), internal energy per mole (U_M, U, or ν). (5) Potential energy (U). (6) Radiant energy (U), spectral radiant energy (U_λ), radiant energy density (u). (7) Reaction velocity (u). (8) Velocity ($\mathbf{u}$), velocity, linear or particle ($\mathbf{u}$), velocity at time t ($\mathbf{u}$ or $\mathbf{u}_t$), velocity, average ($\mathbf{u}_{av}$ or $\bar{\mathbf{u}}$), velocity, group ($\mathbf{u}_g$ or $\mathbf{u}$), velocity components ($\mathbf{u}_x$, $\mathbf{u}_y$, $\mathbf{u}_z$), velocity initial ($\mathbf{u}_0$), velocity, phase or wave ($\mathbf{u}_w$ or $\mathbf{u}_\phi$). (9) Time-independent wave function (u). (10) Uranium (U). (11) Angle of slope (object space) (u). (12) Angle of slope (image space) (u'). (13) In spectroscopy, unsymmetrical (u).

U-CENTER. See **color center.**

U-PROCESS. See **umklapp process.**

UEHLING TERMS. Contribution to the interaction of two particles arising from **vacuum polarization.**

UHF. Abbreviation for **ultra high frequency.**

ULBRICHT SPHERE. An integrating sphere used in a **sphere photometer,** so-called because Ulbricht first used the **Sumptner principle** for this purpose.

ULTRACENTRIFUGE. A **centrifuge** that is operated at extremely high speed and is widely used in research in colloid chemistry and biochemistry.

ULTRAFILTRATION. The separation, by a special method of filtration, of highly dispersed substances in **colloidal solutions,** from the **dispersion medium.** Ultrafilters differ from ordinary filters only in the fineness of the pores through which the liquid must pass. By using a series of filters of graduated fineness it is possible to prepare a series of sols in which the sizes of the disperse phase particles progressively decrease.

ULTRAHIGH FREQUENCY. The band of frequencies between 300 and 3000 megacycles.

ULTRAMICROSCOPE. The ultramicroscope is not an instrument of extraordinary magnifying power, as its name might suggest. The term has reference rather to a special system of illumination for very minute objects. Such objects as colloidal particles, fog drops, or smoke particles are held in liquid or gaseous suspension in an enclosure with an intensely black background (usually of the **black-body** type). They are illuminated by a convergent pencil of very bright light entering from one side and coming to focus in the field of view—the so-called "Tyndall cone" familiar in experiments on **scattering.** With this arrangement, objects too small to form visible images in the microscope produce small **diffraction** ring systems, which appear as minute bright specks on a dark field. The device is used in studying the **Brownian movement,** in the Millikan droplet method of measuring the electronic charge, in observing ionization tracks in the **cloud chamber,** etc.

ULTRAPHOTIC RAYS. Rays beyond the visible region of the **spectrum.** This term is used as a general expression for **ultraviolet** and **infrared rays.**

ULTRASONIC. A modifier indicating a device or system intended to operate at **ultrasonic frequencies.**

ULTRASONIC CAVITATION. See **cavitation.**

ULTRASONIC COAGULATION. The bonding of small particles into larger aggregates by the action of ultrasonic waves.

ULTRASONIC CROSS GRATING (GRATING). A space grating resulting from the crossing of beams of ultrasonic waves having different directions of propagation. This may be two- or three-dimensional. (See also **ultrasonic space grating.**)

ULTRASONIC DELAY LINE (ULTRASONIC STORAGE CELL). A contained medium (usually a liquid, e.g., mercury) in which use is made of the propagation time of sound to obtain a time delay of an ultrasonic signal.

ULTRASONIC DETECTOR. A device for the detection and measurement of ultrasonic waves. Such devices may be mechanical, electrical, thermal, or optical in nature.

ULTRASONIC DETERGENT ACTION. The cleaning effect exhibited by the subjection of clothes, mixed with conventional soap and water solutions, to high intensity ultrasonic radiation.

ULTRASONIC FREQUENCY. A frequency lying above the audio frequency range The term is commonly applied to elastic waves propagated in gases, liquids, or solids.

ULTRASONIC GENERATOR. A device for the production of sound waves of **ultrasonic frequency.**

ULTRASONIC GRATING CONSTANT. The distance between diffracting centers of an ultrasonic wave which is producing particular light diffraction spectra. (See also **ultrasonic space grating.**)

ULTRASONIC LIGHT DIFFRACTION. The formation of optical diffraction spectra when a beam of light is passed through a longitudinal ultrasonic wave field. The diffraction results from the periodic variation of the light refraction in the sound field.

ULTRASONIC MATERIAL DISPERSION. The production of suspensions or emulsions of one material in another due to the action of high-intensity ultrasonic waves

ULTRASONIC MATERIAL TESTING. The use of ultrasonic echo or transmission devices for the detection of flaws, such as hollows or cracks, in optically opaque media

ULTRASONIC SPACE GRATING (GRATING). A periodic spatial variation of the **index of refraction** caused by the presence of acoustic waves within the medium.

ULTRASONIC STORAGE CELL. See **ultrasonic delay line.**

ULTRASONIC STROBOSCOPE. A light interrupter whose action is based on the **modulation of a light beam** by an ultrasonic field.

ULTRASONIC THERMAL ACTION. The temperature rise in the ultrasonic field in a liquid because of the dissipation of the sound by absorption.

ULTRASONIC WAVES. Elastic waves, the frequency of which is above the audible range (i.e., above about 15 kilocycles).

ULTRASONICS. The general subject of acoustic phenomena in the frequency range above the audible frequency range, i.e., above about 15 kilocycles. At one time, this subject was known as supersonics, but such usage is now deprecated.

ULTRAVIOLET RADIATION. A range of radiation of frequencies next higher than those of the visible violet. If light from an open arc is passed through a quartz prism and allowed to fall on a white wall, the familiar **continuous spectrum** appears, ranging from the extreme red to the extreme violet. But if we substitute for the white wall a suitable fluorescent screen, the spectrum is seen to extend considerably beyond the violet, that is, into the region of shorter wavelengths known as ultraviolet. This spectral region has been observed over more than three "octaves" of the radiation frequency scale, roughly, from 1000 A (angströms) at the extremity of the violet to below 400 A on the border of the **x-ray** region. The ultraviolet range has pronounced photographic and ionizing effects, and so is easily detected. The chief hindrance to its study is its rapid absorption in most forms of matter; even air is a serious obstacle to the shorter ultraviolet waves. Therefore, sunlight reaching the earth contains little radiation below 3000 A It is therefore necessary to turn to artificial sources, chief among which are solid-electrode arcs and, especially, the **mercury arc.** Since quartz and fluorite are much more transparent to ultraviolet than is glass, it is necessary that plates, lenses, and prisms for this region be made of these materials Silver is a much poorer reflector of ultraviolet rays than certain alloys, so that mirrors and reflection gratings are made of the latter. Schumann developed the technique of spectroscopy in the far ultraviolet (the "Schumann region") and prepared plates especially adapted to its photography; so that now with the vacuum spectrograph and Schumann plates, the ultraviolet spectra of substances are studied almost as thoroughly as

the visible. The region from the extremity of the visible violet down to 2000 A is sometimes called the "near" ultraviolet, and that from 2000 A down to the border of the x-ray region (below 400 A), the "far" ultraviolet.

UMBRA. See **penumbra.**

UMKLAPP PROCESS. From the German, meaning "flop over process." A type of collision between **phonons,** or between phonons and electrons, where **crystal momentum** is not conserved. This violates no principles, because crystal momentum, or the **wave-vector,** is arbitrary up to the addition of any multiple of a vector of the **reciprocal lattice.** U-processes provide the major part of thermal resistance in dielectric solids, and are important in electrical conduction in metals.

UNAVAILABLE ENERGY. When an **irreversible process** takes place, the effect on the universe is the same as that which would be produced if a certain quantity of energy in a form completely available for work were converted to a form in which it was completely unavailable for work. This amount of energy is called the unavailable energy.

UNCERTAINTY. General term for the estimated amount by which the observed or calculated value of a quantity may depart from the "true" value. The uncertainty is often expressed as the **average deviation,** the **probable error,** or the **standard deviation.**

UNCERTAINTY PRINCIPLE. See **indeterminancy principle.**

UNCONDITIONAL TRANSFER (OF CONTROL). In a **digital computer** which obtains its instructions serially from an ordered sequence of addresses, an instruction which causes the following instruction to be taken from an address which becomes the first of a new sequence.

UNCOUPLING PHENOMENA. Many instances of deviations of observed spectra from those predicted have their origin in the fact that interactions which were neglected or regarded as small in the idealized **coupling cases** really have an appreciable magnitude, and particularly that the relative magnitude of the interactions changes with increasing rotation. Therefore, sometimes, with increasing rotation, a transition takes place from one coupling case to another. Angular momentum vectors coupled to the internuclear axis for small rotation are uncoupled from it with increasing rotation. For detailed discussion, see Herzberg, *Spectra of Diatomic Molecules,* Second Edition (Van Nostrand, New York, 1950).

UNDERCOOLING (SUPERCOOLING). The phenomenon which occurs when a substance is cooled without change of state below the temperature at which its state of aggregation normally changes. The system is then in a **metastable** condition, and a small disturbance often will cause the change in state to take place with evolution of heat and a temperature rise in the system to the normal temperature of the change.

UNDERWATER SOUND PROJECTOR. A **transducer** used to produce sound in water.

UNIAXIAL. Characteristic of or by a single axis, as an object which has only one axis, or a flow of energy that travels only along one axis of a crystal or other medium.

UNIAXIAL CRYSTAL. A birefringent crystal with a single axis along which there is no **double-refraction.**

UNICONDUCTOR WAVEGUIDE. See **waveguide, uniconductor.**

UNIDIRECTIONAL ANTENNA. See **antenna, unidirectional.**

UNIDIRECTIONAL PULSE. See **pulse, unidirectional.**

UNIDIRECTIONAL PULSE TRAIN. See **pulse train, unidirectional.**

UNIFIED FIELD THEORIES. See **field theories, unified.**

UNIFORM. See **analytic.**

UNIFORM MOTION IN A CIRCLE. In order that a particle of mass m be maintained in motion with constant **angular velocity** $\boldsymbol{\omega}$ and at constant radius r from a fixed center, it is necessary that a centripetal force be acting. This force is

$$\mathbf{f} = m\boldsymbol{\omega} \times \boldsymbol{\omega} \times \mathbf{r},$$

where $\mathbf{r}$ is the instantaneous radius vector from the center to the particle. (See **triple vector product.**) This force is always di-

rected toward the center, and has a magnitude

$$f = m\omega^2 r = mv^2/r,$$

where v is the linear speed of the particle. The particle must be continually accelerated inward with an acceleration of magnitude $\omega^2 r$, because the velocity is changing in direction, even though it is constant in magnitude.

UNIFORM PLANE, WAVE. See **wave, uniform plane.**

UNIFORM WAVEGUIDE. See **waveguide, uniform.**

UNILATERAL TRANSDUCER. See **transducer, unilateral.**

UNIMOLECULAR LAYER. Layers having the thickness of a single molecule, such as those of **fatty acids** and **oils** upon water used in the study of **surface tension** phenomena and other properties of surface films.

UNIPOTENTIAL CATHODE. See **equipotential cathode.**

UNIT. (1) A single entity, as one element of apparatus in an industrial plant (2) A standard of measurement as a unit of length, capacity, electromotive force, radiation intensity, etc.

UNIT, ABSOLUTE. An absolute **unit (2)** is one that may be defined in terms of the fundamental units (cf. **unit, fundamental**) of a system of units, without recourse to the introduction of other arbitrary standards. Absolute units are distinguished from gravitational units in mechanics and from the old **International** units in electricity

UNIT AREA ACOUSTIC IMPEDANCE. See **impedance, specific acoustic.**

UNIT CELL. The basic unit of a **crystal structure,** being the minimum volume from which the crystal may be constructed by **translation operations** only.

UNIT, CONCRETE. A unit applied to or associated with a particular magnitude, as one gram.

UNIT, DERIVED. A nonfundamental unit which, however, may be expressed in terms of fundamental units. For example, area, volume, density, etc.

UNIT ELEMENT. A necessary member of every **group.** If the **unit element** is designated by E and if A is any other element of the group, then $EA = AE = A$.

UNIT, FUNDAMENTAL. Any one of the basic set of arbitrarily defined **units (2)** on which a system of units is based. All other units of the system may be derived from the set of fundamental units, and every physical quantity expressed in the system has **dimensions** that may be expressed as combinations of the fundamental units. For the sets of fundamental units in common use, see **Introduction.**

UNIT, M.K.S. A unit in the modification of the metric system which has as its fundamental units the meter, kilogram and second. (See **Introduction.**)

UNIT, METRIC. See **metric system;** also **Introduction.**

UNIT PLANES. Another name for **principal planes** of a lens or optical system.

UNITS OF LENGTH. OPTICAL. See **Siegbahn unit** $= 10^{-11}$ cm, **Ångstrom unit** $= 10^{-8}$ cm, **millimicron** $= 10^{-7}$ cm, **micron** $= 10^{-4}$ cm.

UNITS, SYSTEM OF. A set of definitions of standard physical quantities, in terms of which similar quantities may be measured or expressed, each quantity being specified in terms of some arbitrary standard or by a defining equation, and all of the definitions being mutually consistent.

UNIVARIANT SYSTEM. According to the **phase rule,** a system which has but one **degree of freedom,** e.g., the system liquid water $\rightleftharpoons$ water vapor.

UNIVERSAL FERMI INTERACTION. Interaction between four **fermions** such as

$$N + \bar{\nu} \rightarrow P + e$$

$$P + \mu^- \rightarrow N + \nu$$

$$\mu \rightarrow e + \nu + \bar{\nu}$$

which processes seem to be described by the same coupling constant $g \approx 2 \times 10^{-49}$ erg cm^3.

UNIVERSE, DE SITTER. See **de Sitter universe.**

UNIVERSE, EINSTEIN. See **Einstein universe.**

UNIVERSE, EXPANDING. See **expanding universe.**

UNPOLARIZED LIGHT. While each **photon** is polarized, a finite beam of light consists in general of many photons with their planes of vibration oriented at random about the axis of the beam. Hence, an ordinary beam of light does not show any of the properties of **polarized light.**

UNSTABLE EQUILIBRIUM. See **equilibrium, unstable; stability, mechanical.**

UNSTABLE EQUILIBRIUM OF FLOATING BODY. A floating body is in unstable equilibrium if the **metacenter** is below the **center of gravity.**

URANIUM. Metallic element. Symbol U. Atomic number 92

URANIUM, ALPHA. The allotropic modification of **uranium** metal which is stable below approximately 660°C. It has an orthorhombic crystal structure.

URANIUM, BETA. That allotropic modification of **uranium** metal which is stable between approximately 660°C and 770°C. The structure has been determined to be orthorhombic.

URANIUM, GAMMA. That allotropic modification of **uranium** metal which is stable above approximately 770°C. It has a body-centered cubic structure

USEFUL MAGNIFICATION. Discussed under **empty magnification.**

UTILIZATION FACTOR. When a **transformer** is used to supply a **rectifier** system the current wave forms are normally irregularly shaped and hence the losses are different than would be expected at first glance, the transformer running hotter for a given current than if it were supplying a **resistance** load The ratio of the d-c power output to the normal a-c rating for the same heating losses is the utilization factor of the transformer

UVIOL GLASS. A glass developed by Schott, which is highly transparent to the **ultraviolet.**

V

V. (1) Volume (v or V), volume, molecular (V), volume of a cavity or room (V), volume of configuration space (V), volume, total (V), volume, specific (v), volume per unit mass (v), volume of atom or molecule (v or v_m), volume per mole (v, V_m or V), volume, critical (V_c), atomic volume (V). (2) Velocity (**v**), velocity, linear or partial (**v**), velocity at time t (**v** or $\mathbf{v}_t$), velocity, average ($\mathbf{v}_{av}$ or **v**), velocity, group ($\mathbf{v}_g$ or **v**), velocity components ($\mathbf{v}_x$, $\mathbf{v}_y$, $\mathbf{v}_z$), velocity initial ($\mathbf{v}_0$), velocity of sound or other waves (**v**). (3) Vanadium (V). (4) Potential, electric (V), potential difference, steady a-c (V), potential difference, rms or effective (V), potential difference, average (V or V_{av}), potential difference, Peltier (V_π), potential difference, Seebeck (V_s), potential difference, Thomson (V_t), potential difference, average (V_{av}), potential difference, contact or Volta (V_c), potential difference, excitation (V_e), potential difference, maximum (V_m or V_{max}), potential difference (V, V_p or V_{pl}) (4) Inner potential of metals (V or V_i). (5) Ionization potential (V or V_i). (6) Potential energy (V or U or E_p). (7) Vibrational quantum number (v). (8) Verdet constant, specific magnetic rotation (V).

V ANTENNA. See **antenna, V.**

V_1 CENTER. See **color center.**

VACANCY. A site in the **crystal lattice** of an **ionic crystal** from which the ion which should be present is missing.

"VACUSTAAT." A form of McLeod gauge (see **gauge, McLeod**) useful in the range 10–10^{-2} mm Hg.

VACUUM. Theoretically a space devoid of matter; practically a region of space in which the atmospheric pressure has been reduced as much as possible with present pumping systems, or as much as is necessary to prevent influence of the atmosphere on processes being carried on within the space.

VACUUM CUT-OFF, HIGH. A device which permits the apparatus being exhausted to be temporarily disconnected from the pump.

VACUUM ELECTRON. In the **Dirac electron theory,** an electron in one of the negative energy states which are supposed to be all filled for the case of a vacuum.

VACUUM LEAK DETECTORS. Devices, operating on several principles, which are used to detect and locate leaks in high-vacuum systems. One of the most sensitive leak detectors is a **mass spectrometer** which can detect as little as one part of helium (introduced at the leak) in 4×10^5 parts of air at an operating pressure of 3×10^{-4} mm Hg. A more commonly used leak detector for glass vacuum systems is a **Tesla coil,** one terminal of which is moved over the surface of the glass. A visible discharge through the glass often appears at the leak.

VACUUM METER, PHILIPS. A form of gas-discharge gauge in which a magnetic field together with **good geometry** of the electrodes increases the ionization by a large factor, enabling the discharge to be self-maintained at a much lower pressure than would otherwise be possible.

VACUUM POLARIZATION. Process by which an electromagnetic field generates virtual electron-positron pairs which modify the charge and current distribution which produced the original electromagnetic field. The effect lifts the $2S_{1/2}$ state of hydrogen by 27 megacycles, and, for example, the $3D$ state of a Pb-μ **mesonic atom** by approximately 9200 electron-volts.

VACUUM PUMP. See **pump, vacuum.**

VACUUM RESERVOIR. A large vessel inserted between the **fore pump** and high vacuum pump in a **vacuum pump system.** When evacuated to the fore vacuum it may be sealed off from the fore pump, thus permitting the fore pump to be turned off.

VACUUM SPECTROGRAPH. See **spectrograph, vacuum.**

VACUUM THERMOCOUPLE. (1) A device for measuring very feeble electric currents, either alternating or direct, by means of their heating effect. The current to be measured is passed through a short, very fine platinum wire enclosed in a small, evacuated glass bulb. In good thermal contact with the center of this wire is placed one junction of a small **thermocouple** composed of platinum platinum-rhodium wires (or other metals), the other junction being kept at the constant temperature for which the instrument has been calibrated. When the unknown current is turned on, it heats the fine platinum wire slightly, and sets up a change of electromotive force in the couple which bears a definite relation to the heating current, as determined by calibration with known currents This voltage change may, if necessary, be amplified by a d-c **amplifier** in order to make it measurable. The glass bulb containing the thermocouple must be housed in a heat-insulating, opaque box or case to prevent heat from reaching the couple by either radiation or conduction, and thoroughly evacuated to avoid convection (2) An arrangement similar to that described above, but without a heating element, used for the measurement of radiation The junction is attached to a receiver, on which the radiation falls and which is heated by it Very often two junctions and two receivers are included in the evacuated envelope, the second acting as a compensating device for the first, on which the radiation falls. Disturbances due to changes in **ambient temperature** are thus largely eliminated

VACUUM TUBE. See **tube, vacuum.**

VACUUM-TUBE AMPLIFIER. See **amplifier, vacuum-tube.**

VACUUM-TUBE TRANSMITTER. See **transmitter, vacuum-tube.**

VACUUM-TUBE VOLTMETER. See **voltmeter, vacuum-tube.**

VALENCE. The property of an atom or radical to combine with other atoms or radicals in definite proportions, or a number representing the proportion in which a given atom or radical combines. The standard of reference is hydrogen, which is assigned a valence of 1, and the valence of any given atom or radical is then the number of hydrogen atoms, or their equivalent, with which the given atom or radical combines Many elements have more than one valence, and their compounds are classified and designated accordingly.

VALENCE, ACTIVE. The **valence** which an element exhibits in any particular compound, e g , the active valence of iron in the ferrous salts is two.

VALENCE ANGLES. Angles between the successive valence **bonds** of an atom.

VALENCE, ANOMALOUS. An exceptional **valence** that an element has in certain compounds.

VALENCE BAND. The range of energy states in the spectrum of a solid crystal in which lie the energies of the **valence electrons** which bind the crystal together. In an insulating or semiconducting material, the band below the **conduction band.** Instead of the valence electrons being thought of as localized in bonds, they are supposed to be spread into a filled band.

VALENCE, CO-. See **covalence.**

VALENCE CRYSTAL. A crystal bound together by **covalent bonds.**

VALENCE, DATIVE. A **covalence** in which one of the two atoms joined by the valence bond furnishes both of the shared electrons

VALENCE, ELECTRO-. A **valence** that is due to the transfer of an electron or electrons from one atom to another.

VALENCE ELECTRON. An electron in the outer shell of an atom. Such electrons are called valence electrons because, by gaining, losing, or sharing these outer-shell electrons, atoms combine to form molecules Therefore, the number of these outer-shell electrons often determines the valence or valences of the atom. (See **atomic structure.**)

VALENCE FORCE FIELD. An assumed force field utilized in order to solve the equation in which the potential energy of vibration of a polyatomic molecule is expressed in terms of the energies of the restoring forces of each atom and the energies of their interaction

terms. This simplifying assumption is that a force constant is associated with every valence bond and every valence angle, representing their resistance to change in length or magnitude.

VALENCE, FREE. A valence that does not appear to be satisfied, as the valence of a **free radical.**

VALENCE, MAXIMUM. The highest valence shown by an element in any of its compounds. With chromium it is six; potassium, one; nitrogen, five; etc.

VALENCE, NEGATIVE. An **electro-valence** possessed by an atom because it has become ionized by addition of an electron or electrons.

VALENCE, NORMAL. The valence that an element exhibits in a majority of its compounds.

VALENCE, NULL. According to the electronic conception of valence, a condition in which an element has no valence because, in its normal state, it has a complete outer electronic shell, as in the case of the inert gases of the atmosphere and radon.

VALENCE NUMBER. A number assigned to an atom or ion that is equal to its valence, preceded by a plus or minus sign to indicate whether the ion is positive or negative, or whether the atom, in reaching the state of oxidation under consideration, has lost or gained electrons from its normal state. The basis of this computation of positive and negative numbers is the assignment to hydrogen ions or combined atoms (except in metallic hydrites) of a value of +1. The other elements are then assigned valence numbers such that in any stable molecule the sum of the valence numbers is zero.

VALENCE, POSITIVE. A valence state of an atom in which the **valence number** is positive.

VALENCE SHELL. The group of electrons constituting the outer electronic shell of an atom. (See **valence electron.**)

VALENCE, SUPPLEMENTARY. A residual valence connecting atoms, groups, or molecules in which the ordinary valences are already saturated. Supplementary valences are found in **coordination compounds** and often in **associated molecules.**

VALENCY, THEORY OF. The theory that atoms combine with other atoms in proportions which are determined by a property known as valence, the standard of which is the valence of hydrogen taken as one, or, better, of oxygen taken as two. This conception has been extended to include combinations entered into by groups of atoms as well as individual atoms. The present conception of the mechanism of the process is by the transfer or sharing of electrons between atoms. (See **valence,** and various entries under the term **atom.**)

VALLEY BREEZE. On hot days, uneven terrain gives rise to uphill breezes, i.e., from the valley up mountain or hill slopes This breeze is known as a valley breeze; it is an **anabatic wind.** With sunset, the breeze dies

VALUE. The amount or magnitude of a quantity or property.

VALUE OF ISOTOPE MIXTURE. A measure of the difficulty of preparing a quantity of an isotope mixture. It is proportional to the amount of the mixture, and is also a function of the composition of the mixture. The change in value created by a **cascade** is directly proportional to the number of separating elements it contains. For a binary mixture, the value of Q moles of mixture, taking the equimolar mixture as the reference state, is given by

$$Q(2N - 1) \ln R$$

when N is the mole fraction of either component, R is $N/1 - N$, the molecular abundance ratio.

When referred to an arbitrary mole fraction N_0 as the reference state the value of Q moles of mixture is

$$V = \left\{(2N - 1) \ln \frac{N(1 - N_0)}{N_0(1 - N)} + \frac{(N - N_0)(1 - 2N_0)}{N_0(1 - N_0)}\right\} Q.$$

The total value created by a separating plant is the difference between the total value of all outgoing materials and the total value of all ingoing materials. This resultant is independent of N_0.

VANADIUM. Metallic element. Symbol V. Atomic number 23.

VAN DE GRAAFF, GENERATOR. See **electrostatic generator.**

VAN DER WAALS ADSORPTION. See **adsorption, types of.**

VAN DER WAALS EQUATION. A form of the **equation of state,** relating the pressure, volume, and temperature of a gas, and the gas constant. Van der Waals applied corrections for the reduction of total pressure by the attraction of molecules (effective at boundary surfaces) and for the reduction of total volume by the volume of the molecules. The equation takes the form

$$\left(P + \frac{a}{V^2}\right)(V - b) = RT$$

in which P is the pressure of the gas, V is the volume, T is the absolute temperature, R is the gas constant, and a and b are correction terms which have been evaluated and reported for many gases.

VAN DER WAALS FORCES. Interatomic or intermolecular forces of attraction due to the interaction between fluctuating **dipole moments** associated with molecules not possessing permanent dipole moments. These dipoles result from momentary dissymmetry in the positive and negative charges of the atom or molecule, and on neighboring atoms or molecules. These dipoles tend to align in antiparallel direction and thus result in a net attractive force. This force varies inversely as the seventh power of the distance between ions.

VAN DER WAALS SURFACE TENSION RELATIONSHIP.

$$\gamma = A(\rho_c/M)^{2/3}T_c(1 - T/T_c)^B$$

where A is a constant, $B \simeq 1.23$, ρ_c is the density at the critical temperature, M is the molecular weight, γ is the surface tension at temperature T.

VAN'T HOFF EQUATION. A relationship representing the variation with temperature (at constant pressure) of the equilibrium constant of a gaseous reaction in terms of the change in **heat content,** i e., of the heat of reaction (at constant pressure). It has the form:

$$\frac{d \ln K_p}{dT} = \frac{\Delta H}{RT^2}$$

in which K_p is the equilibrium constant at constant pressure, T is absolute temperature, R is the gas constant, and ΔH is the standard change in heat content, or, for ideal gases, the change in heat content.

VAN'T HOFF FACTOR. A factor which expresses the ratio of the observed **osmotic pressure** of a solution to the value calculated upon the basis of ideal behavior, i.e., direct proportionality of the osmotic pressure to the product of the temperature and the gas constant, divided by the volume.

VAN'T HOFF LAW. A dissolved substance has the same **osmotic pressure** as the gas pressure it would exert in the form of an **ideal gas** occupying the same volume as that of the solution.

VAPOR. A substance in the gaseous state, but below its critical temperature, is called a vapor. If a pure liquid partly filling a closed container is allowed to stand, the space above it becomes filled with the vapor of the liquid, which develops a pressure. This **vapor pressure** increases up to a certain limit, depending upon the temperature, where it becomes constant, and the space is then said to be saturated.

Such a body of vapor is not subject to all of the laws of gases. If the space occupied by it is diminished without change of temperature, there is no increase in pressure, but instead part of the vapor condenses. And if the temperature is raised, the pressure goes up not at a uniform but at an increasing rate, because of both the expansion of the liquid and the further **evaporation** from it. The relation of vapor to liquid takes on a curious aspect as the **critical state** is approached, in which the vapor and the liquid have equal density.

VAPOR CAPACITY OF AIR. See **saturation.**

VAPOR DENSITY. The density of a gas referred to the density of hydrogen or air as unity. If the density of hydrogen is taken as 2, the vapor density is approximately the molecular weight; if it is taken as one, the vapor density equals about half the molecular weight.

VAPOR PRESSURE. The vapor pressure of a substance (solid or liquid) is the pressure

exerted by its vapor when in **equilibrium** with the substance. For pure substances it depends only on the temperature. The simplest way to measure the vapor pressure of a substance is to introduce a small amount of it into the closed end of a barometer tube and note the decrease in the height of the barometer.

The vapor pressure of a **solvent** is lowered on dissolving the solute in it. This lowering for dilute solutions is proportional to the mole fraction of the solute (see **Raoult law**). The lowering of the vapor pressure of the solution can be related to the lowering of the freezing point and the elevation of the boiling point. These phenomena serve as a basis for **molecular weight** determinations. If both components of the solution are volatile, each lowers the vapor pressure of the other and the ratios of the two substances in the liquid and vapor phase are not necessarily the same Use is made of this fact to separate the two substances by **distillation.**

VAPOR PRESSURE, CHEMICAL CONSTANT OF. The constant of integration in the general vapor-pressure equation for a substance (see **vapor pressure, general equation**). Its value can be found both by measurement of the other quantities in the equation, and from **statistical mechanics.**

VAPOR PRESSURE, GENERAL EQUATION. Equation for the vapor pressure of a solid obtained by integration of the **Clausius-Clapeyron equation,** assuming that the vapor obeys the **ideal gas law:**

$$\ln p = -\frac{\lambda_0}{RT} + \frac{S}{2}\ln T - \frac{1}{R}\int_0^T \frac{\int_0^T (C_s - C_i)dT}{T^2}dT + i.$$

In this equation, p is the vapor pressure, R, the **gas constant,** T, the absolute temperature, C_s the molar specific heat of the solid, and C_i the internal molar specific heat of the vapor due to rotations and vibrations. λ_0 and i are constants of integration known as the **latent heat of vaporization** and the **chemical constant** respectively. The equation is slightly different for the case of a liquid.

VAPOR PRESSURE, KIRCHHOFF FORMULA FOR. Special case of the **vapor pressure general equation** in which the integration is taken between temperature limits sufficiently close for the specific heats to be regarded as constant. This gives the equation

$$\ln p = A - \frac{B}{T} - C\ln T$$

where p is the vapor pressure, T the absolute temperature, and A, B, and C are constants.

VAPOR PRESSURE, METHODS OF MEASUREMENT. (1) Methods for the measurement of the saturation vapor pressure at a known temperature are:

(a) Static method, in which the pressure of vapor in equilibrium with liquid is measured directly by a mercury **manometer** or otherwise.

(b) By measuring the variation of boiling-point with pressure in an atmosphere which neither dissolves in nor reacts with the liquid.

(c) By measuring the rate of transpiration of the vapor into a vacuum through a small hole in a container filled with vapor at the saturation pressure. This may be done by weighing, and is especially suitable for the measurement of extremely low vapor pressures.

(2) To measure the partial pressure of a vapor in the presence of other gases, several methods are available:

(a) Wet and dry bulb (differential) thermometer. The vapor pressure is determined by observing the temperature difference between a surface wetted with the liquid (usually water) and exposed to a suitable current of the gas-vapor mixture and a similar dry surface.

(b) Dew-point method. A bright surface is cooled until vapor is just on the point of depositing. The partial pressure in the mixture equals then the saturation vapor pressure at this temperature.

(c) By absorbing chemically the vapor from a known quantity of the mixture and weighing. (See also **Dumas method; Hofmann method; Victor Meyer method; Fairbairn and Tate method; Knudson method; Langmuir method; constant volume method; boiling method; direct or static methods.)**

VAPOR PRESSURE, REID. The vapor pressure of a liquid determined at 100°F and expressed in pounds per square inch.

VAPOR PRESSURE, RELATIVE LOWERING OF. A quantity given by the expression

$$\frac{p_0 - p}{p_0}$$

where p_0 is the vapor pressure of pure solvent, and p is the vapor pressure of the solution.

VAPOR, SATURATED. A vapor that is in **equilibrium** with its liquid at a given temperature.

VAPOR TENSION. The tendency of a liquid to enter the vapor state, balanced by, and numerically equal to, the **vapor pressure.**

VAPORIMETER. An instrument used to determine the vapor tension of a substance, particularly that of alcoholic liquids, whereby their content of alcohol may be estimated

VAPORIZATION. The change of a substance from the liquid or solid state to the gaseous state.

VAPORIZATION, HEAT OF. (LATENT HEAT OF VAPORIZATION, HEAT OF EVAPORATION). The amount of heat required to convert a unit mass of a substance into its vapor at the vapor pressure of the system and without temperature change. The amount of heat required varies with the temperature at which the evaporation is carried on, generally decreasing as the temperature increases.

VAPORIZATION, MOLAR LATENT HEAT OF (MOLECULAR HEAT OF VAPORIZATION). The amount of heat required to convert one gram-molecule of substance into its vapor at a constant temperature and at the vapor pressure of the system; numerically this quantity is equal to the product of the heat of vaporization and the **gram-molecular weight.**

VAR. Abbreviation for **volt-ampere, reactive.**

VARIABLE. A quantity, as distinguished from a **constant,** to which any number of values in a given **set** may be assigned. The numbers may be **real** or **complex** If the set comprises a **domain** (a,b), then the variable is only defined over this interval and all values outside of the interval are ignored.

When an **implicit function** defines a relation between two or more variables, it may usually be solved to find an **explicit function** of the form such as $y = f(x,z,\cdots)$. The variables x, z, $\cdots$ are independent, for values must be given to each of them in order to fix the dependent variable y. Choice of the dependent and independent variables can be made as desired in a given problem but some particular choice is likely to be more convenient than others.

VARIABLE FOCUS LENS. A lens system, part of which is movable, and so designed as to have correction for lens **aberrations,** continual sharp focusing of the image on the receiving film and constant **f-value** as the focal length is changed. Such a lens gives the effect of moving the camera towards or away from the object Variable focus lenses are used in motion picture and television cameras; commonly called Zoomar lenses.

VARIABLE-INDUCTANCE PICKUP. See **pickup, variable-inductance.**

VARIABLE IMPEDANCE TUBE. See **tube, reactance.**

VARIABLE-MU TUBE. See **tube, variable-mu.**

VARIABLE RELUCTANCE CARTRIDGE. See **reluctance cartridge.**

VARIABLE RELUCTANCE MICROPHONE. See **microphone, variable reluctance.**

VARIABLE - RELUCTANCE PICKUP (MAGNETIC PICKUP). See **pickup, variable-reluctance (magnetic pickup).**

VARIABLE - RESISTANCE PICKUP. See **pickup, variable-resistance.**

VARIABILITY. The property of departing from an established value or standard, or the amount of such departure.

VARIANCE. Either the number of **degrees of freedom** possessed by a system, or the degrees of freedom themselves. (See also **phase rule.**)

VARIATIONAL METHOD. An approximation method of calculating an upper limit to the lowest **energy state** of a system by substituting in the so-called variational integral an arbitrary function in place of the true wave function.

VARIATIONAL PLATE RESISTANCE. See **dynamic plate resistance.**

VARIGNON THEOREM. The algebraic sum of the moments of two coplanar concurrent forces with respect to a point in their plane is equal to the moment of the resultant with respect to the same point.

VARIOCOUPLER. A **radio-frequency transformer** in which one of the windings may be rotated with respect to the other, in order to change the coefficient of **coupling.**

VARIOMETER. A **variable inductor** in which the variation of inductance is obtained from the change in mutual inductance between two coils as one is rotated with respect to the other.

VARISTOR. A two-electrode **semiconductor** device having a voltage-dependent, nonlinear resistance.

VECTOR. A quantity possessing both magnitude and direction, as distinguished from a **scalar** which has magnitude only. Typical vectors are the displacement, velocity, and acceleration of a particle; its mass, temperature, and density are scalars. A more precise definition of a vector is often required Suppose a point, located in a rectangular coordinate system has components (x_1,x_2,x_3). The same point, however, could also be described in other coordinate systems, obtained from the first one by translation of the origin and rotations about the coordinate axes. If the components of the point in the second system are (x_1',x_2',x_3'), assumed for convenience to have the same origin as that of the first system, then the relation between the components, called a **linear transformation,** is

$$x_i' = \sum_{j=1}^{3} c_{ij}x_j; \quad i = 1, 2, 3$$

where the c_{ij} are the nine **direction cosines** between the various coordinate-axis pairs. **Matrix** notation may also be used to write $\mathbf{x}' = \mathbf{R}\mathbf{x}$, where $\mathbf{x}'$ and $\mathbf{x}$ are column vectors; $\mathbf{R}$ is the **orthogonal matrix** of the direction cosines. If this transformation law does not hold, the directed line segment from the coordinate origin to the point is not a vector but it may be a **pseudovector.** The vector concept is readily extended to an abstract vector space of n dimensions.

VECTOR ADDITION. If **A**, **B** are **vectors** with components A_x, A_y, A_z and B_x, B_y, B_z, respectively, their sum is a new vector $\mathbf{C} = \mathbf{A} + \mathbf{B}$, with components $A_x + B_x$, $A_y + B_y$, $A_z + B_z$. Vector addition obeys the **commutative** and **associative laws** of algebra: $\mathbf{A} + \mathbf{B} = \mathbf{B} + \mathbf{A}$; $(\mathbf{A} + \mathbf{B}) + \mathbf{C} = \mathbf{A} + (\mathbf{B} + \mathbf{C})$. To subtract a vector **B** from a vector **A**, take the negative of **B** and add $-\mathbf{B}$ to **A**.

VECTOR, AXIAL. Also called a rotor. (See **pseudovector.**)

VECTOR, COMPONENT OF. **Scalar** quantities, required to determine a **vector** numerically. In three dimensions, they are directed lines, parallel to the axes of a coordinate system. Thus, if a rectangular Cartesian system is used with **unit vectors i, j, k,** any vector may be written as $\mathbf{A} = \mathbf{i}A_x + \mathbf{j}A_y + \mathbf{k}A_z$, where (A_x,A_y,A_z) are its three **components.** In the more general case of an n-dimensional vector the components of the vector are the n **matrix elements** of a column or a row matrix.

VECTOR, CONTRAVARIANT AND COVARIANT. See **contravariant vector;** also **tensor, contravariant** and **covariant.**

VECTOR, COVARIANT. See **covariant vector.**

VECTOR DERIVATIVE. If a **vector R** is a function of a single **scalar** variable t, there are three possible ways in which **R** may vary with t, for if $\mathbf{R}_1$ and $\mathbf{R}_2$ refer to t_1 and t_2, respectively, then $\mathbf{R}_2$ may differ from $\mathbf{R}_1$: (1) in magnitude only; (2) in direction only; (3) in both magnitude and direction. Since even the general case is relatively simple, assume that a curve is traced by the terminus of the continuously varying vector **R**, the **origin** of the vector being kept fixed at the origin of a coordinate system. Let A and B be two neighboring points on this curve and let $\mathbf{R}_1$ and $\mathbf{R}_2$ be their position vectors, then the vector $\Delta\mathbf{R} = \mathbf{R}_2 - \mathbf{R}_1$ has the direction of the secant AB, which approaches the tangent to the curve at A as $\Delta t = t_2 - t_1$ approaches zero. The quotient $\Delta\mathbf{R}/\Delta t$ is the average rate of change of **R** in the interval between t_1 and t_2. The derivative is defined as

$$\lim_{\Delta t \to 0} \frac{\Delta\mathbf{R}}{\Delta t} = \frac{d\mathbf{R}}{dt}.$$

In terms of **unit vectors,** and with the use of primes for differentiation, $\mathbf{R} = \mathbf{i}R_x + \mathbf{j}R_y + \mathbf{k}R_z$; $\mathbf{R}' = \mathbf{i}R_x' + \mathbf{j}R_y' + \mathbf{k}R_z'$; $\mathbf{R}'' = \mathbf{i}R_x'' + \mathbf{j}R_y'' + \mathbf{k}R_z''$. For a composite function of two or more vectors, each depending on a single scalar t, the usual rules of differentiation hold except that the order of the vectors must be retained, if vector products are involved.

VECTOR, ENTROPY. See **entropy vector.**

VECTOR FIELD. A region of space, each point of which is described by a **vector.** Thus, in three dimensions, each point is described by three quantities, the **components** of the vector along the coordinate axes. Examples are wind velocities in the atmosphere, electrostatic or electromagnetic fields. (See also **scalar field.**)

VECTOR FLUX. If $\mathbf{V}$ describes a **vector field,** for example the velocity of an incompressible fluid, then the total **flux** through a surface S in the field is given by

$$\iint_S \mathbf{V}\cdot d\mathbf{S}.$$

The vector $\mathbf{V}$ may refer to electric, magnetic, or gravitational force; heat or a fluid, etc. The **surface integral** may be converted to a **volume integral** by **Gauss's theorem.**

VECTOR, FOUR. A **vector** with four **components.** One type is called a **quaternion.** Another, used principally in relativity theory, has for its components (x, y, z, ict), where x, y, z are positional coordinates, $i = \sqrt{-1}$, c is the velocity of light, and t is the time. The components of the vector in one coordinate system are related to the components in another system by a **Lorentz transformation.**

VECTOR FUNCTION. If (x',y',z') are functions of (x,y,z), then the vector $\mathbf{V}' = \mathbf{i}x' + \mathbf{j}y' + \mathbf{k}z'$ is a **vector function** of the vector $\mathbf{V} = \mathbf{i}x + \mathbf{j}y + \mathbf{k}z$, where $(\mathbf{i},\mathbf{j},\mathbf{k})$ are **unit vectors.** The function is a **linear vector function** if $\mathbf{V}'(\mathbf{A} + \mathbf{B}) = \mathbf{V}'(\mathbf{A}) + \mathbf{V}'(\mathbf{B})$, for all vectors $\mathbf{A}$, $\mathbf{B}$.

VECTOR INTEGRAL. The **inverse operation** to **vector differentiation.** Corresponding to ordinary definite integrals there are **line integrals, surface integrals,** and **volume integrals** of vector functions.

VECTOR, IRROTATIONAL. If the **curl** of **a vector function** of position vanishes everywhere in a certain region, the function is said to be an **irrotational** vector (or a **lamellar** vector) in this region. It follows that if $\mathbf{V}$ is an irrotational vector so that $\nabla \times \mathbf{V} = 0$, then $\mathbf{V} = \nabla\phi$, where ϕ is some **scalar** function of position.

VECTOR, LAMELLAR. See **vector, irrotational.**

VECTOR MULTIPLICATION. There are two distinct kinds of products of two vectors: the **scalar product** and the **vector product** (but see also **pseudovector**). Combining these two types of products, there are three kinds of **triple products of vectors,** and several **quadruple products of vectors,** giving rise to the **vector system, reciprocal.**

VECTOR NOTATION. A **vector** is commonly indicated by a bold-face letter such as $\mathbf{A}$, which stands for its three **scalar components** (A_1, A_2, A_3) referred to some coordinate system. In the Gibbs notation, **scalar** and **vector products** are shown with dots and crosses, respectively Thus, if C is a scalar and $\mathbf{V}$, $\mathbf{A}$, $\mathbf{B}$ are vectors, then $C = \mathbf{A}\cdot\mathbf{B}$ and $\mathbf{V} = \mathbf{A} \times \mathbf{B}$ Less commonly used symbols, have been proposed by Hamilton, Grassmann, Heaviside, and others. They include: $T\mathbf{A}$ (T for **tensor**), $|A|$ for the magnitude of a vector; $S\mathbf{AB}$, $(\mathbf{AB})$ for the scalar product; $V\mathbf{AB}$, $\mathbf{A}\wedge\mathbf{B}$, and $[\mathbf{AB}]$ for the vector product.

VECTOR, ORIGIN OF. A **vector** is often indicated graphically by means of an arrow (technically called a stroke). The length of the arrow is proportional to the **scalar** magnitude of the vector and the direction in which the arrow points is the direction of the vector The tail or initial point of the arrow is its **origin;** the head or final point is its **terminus.**

VECTOR, ORTHOGONAL. A vector $\mathbf{A}$ perpendicular to another vector $\mathbf{B}$. Their **scalar product** vanishes, or $\mathbf{A}\cdot\mathbf{B} = 0$.

VECTOR, POLAR. Also called a proper **vector** or a localized vector. If its components in one Cartesian coordinate system are given by the column vector $\mathbf{x}$, then its components in another such system are $\mathbf{x}' = \mathbf{R}\mathbf{x}$, where $\mathbf{R}$ is an **orthogonal matrix.** A directed

quantity which cannot satisfy this requirement is a **pseudovector.**

VECTOR, POSITION. If, in a rectangular coordinate system, a point has coordinates (x,y,z) then its position vector is one drawn from the coordinate origin to the point. It may be written as $\mathbf{R} = \mathbf{i}x + \mathbf{j}y + \mathbf{k}z$, where $(\mathbf{i,j,k})$ are **unit vectors.**

VECTOR POTENTIAL. (1) Three functions of position and time, forming a vector $\mathbf{A}$ $(\mathbf{r},t)$ in ordinary space, used together with the **scalar potential** ϕ to specify an electromagnetic field. In **Minkowski space,** A_x, A_y, A_z, $i\phi$ form the components of a **four-vector.** In Gaussian units the electromagnetic field is given by

$$\mathbf{B} = \nabla \times \mathbf{A}$$

$$\mathbf{E} = -\nabla\phi - \frac{1}{c}\frac{\partial \mathbf{A}}{\partial t}.$$

(2) A solenoidal **vector field,** such as **magnetic induction,** is one whose **divergence** vanishes everywhere: $\nabla \cdot \mathbf{B} = 0$ Such a vector is derivable from a vector potential; i.e., we can write $\mathbf{B} = \nabla \times \mathbf{A}$. The vector potential due to a distribution of current density is

$$\mathbf{A} = \mu \int \mathbf{J} \frac{1}{r}\, dv$$

where r is the distance between the point of observation and dv, the volume element. For a closed linear current loop, this becomes

$$\mathbf{A} = \mu I \int \frac{1}{r}\, d\mathbf{l}$$

so that

$$\mathbf{H} = \mathbf{B}/\mu = \nabla \times \mathbf{A}/\mu$$

$$= I \int \nabla\left(\frac{1}{r}\right) \times d\mathbf{l} = I \int \frac{d\mathbf{l} \times \mathbf{r}}{r^3}.$$

Thus result is often expressed by the (non-unique) resolution into differential elements:

$$d\mathbf{H} = I \frac{d\mathbf{l} \times \mathbf{r}}{r^3}$$

which is known as the **Ampere law,** or the **Biot-Savart law.**

VECTOR PRODUCT. See **vector multiplication.**

VECTOR, RADIUS. In **polar coordinates** or in **spherical polar coordinates, a vector** drawn from the origin of the coordinate system to a point. It is thus one of the two or three quantities required to describe the position of the point in the coordinate system.

VECTOR, SOLENOIDAL. If the **divergence** of a **vector function** of position vanishes everywhere in a certain region, the function is said to be a **solenoidal** vector in that region. It follows that if $\mathbf{V}$ is a solenoidal vector so that $\nabla \cdot \mathbf{V} = 0$, then $\mathbf{V} = \nabla \times \mathbf{W}$, or $\mathbf{V}$ is the **curl** of some vector $\mathbf{W}$.

VECTOR SPACE. A generalization of ordinary three-dimensional space to n dimensions. A **vector** in such space, if its components are **real** numbers $x_1, x_2, \cdots, x_n$ may be considered as a row or column matrix $\mathbf{x}$. The **scalar product** of two vectors $\mathbf{x}$ and $\mathbf{y}$ is a **scalar**

$$\tilde{\mathbf{x}}\mathbf{y} = x_1y_1 + x_2y_2 + \cdots + x_ny_n$$

where $\tilde{\mathbf{x}}$ is the **transpose** of $\mathbf{x}$ and two vectors are **orthogonal** in such a space if their scalar product vanishes, $\tilde{\mathbf{x}}\mathbf{y} = 0$. The square of the length of the vector (or its **norm** squared) is also a scalar

$$N^2 = \tilde{\mathbf{x}}\mathbf{x} = x_1^2 + x_2^2 + \cdots + x_n^2.$$

If $N = 1$, the vector is **normalized.**

If the components of the vector are **complex,** the space is a **Hermitian** (or **unitary**) space. The **Hermitian scalar product is**

$$\mathbf{x}\dagger\mathbf{y} = x_1{}^*y_1 + x_2{}^*y_2 + \cdots + x_n{}^*y_n$$

where $\mathbf{x}\dagger$ is the **associate matrix** to $\mathbf{x}$ and $x_i{}^*$ is the **complex conjugate** to x_i. The norm is defined by $N^*N = \mathbf{x}\dagger\mathbf{x}$ The condition for orthogonality is $\mathbf{x}\dagger\mathbf{y} = \mathbf{y}\dagger\mathbf{x} = 0$ and the vector is normalized if $\mathbf{x}\dagger\mathbf{x} = 1$.

VECTOR, STATE. See **state vector.**

VFCTOR SYSTEM, RECIPROCAL. From the properties of the **quadruple product of vectors,** the following relation is found to hold for any four vectors $\mathbf{r}$, $\mathbf{a}$, $\mathbf{b}$, $\mathbf{c}$:

$$\mathbf{r}[\mathbf{abc}] = [\mathbf{rbc}]\mathbf{a} + [\mathbf{rca}]\mathbf{b} + [\mathbf{rab}]\mathbf{c}$$

which may also be written in the equivalent form

$$\mathbf{r} = \mathbf{r}\cdot\mathbf{a}'\mathbf{a} + \mathbf{r}\cdot\mathbf{b}'\mathbf{b} + \mathbf{r}\cdot\mathbf{c}'\mathbf{c}.$$

The system of three vectors

$$\mathbf{a}' = \frac{\mathbf{b} \times \mathbf{c}}{[\mathbf{abc}]}; \quad \mathbf{b}' = \frac{\mathbf{c} \times \mathbf{a}}{[\mathbf{abc}]}; \quad \mathbf{c}' = \frac{\mathbf{a} \times \mathbf{b}}{[\mathbf{abc}]}$$

is reciprocal to the three non-coplanar vectors **a**, **b**, **c**. The unit vectors **i**, **j**, **k** form a system which is its own reciprocal. Conversely, a system which is its own reciprocal is a set of mutually perpendicular unit vectors, forming either a right-handed or left-handed Cartesian coordinate system.

VECTOR, TERMINUS OF. See **vector, origin of.**

VECTOR, UNIT. A **vector** of unit length, drawn in the positive direction and tangential to a coordinate system It is not necessary that the system be **orthogonal.** In the common case, a rectangular Cartesian coordinate system is used and the unit vectors along the OX, OY, and OZ axes are called **i**, **j**, **k**, respectively. **Scalar** and **vector products** of unit vectors in this case have the following properties:

$$\mathbf{i}\cdot\mathbf{j} = \mathbf{j}\cdot\mathbf{i} = \mathbf{i}\cdot\mathbf{k} = \mathbf{k}\cdot\mathbf{i} = \mathbf{j}\cdot\mathbf{k} = \mathbf{k}\cdot\mathbf{j} = 0$$

$$\mathbf{i}\cdot\mathbf{i} = \mathbf{j}\cdot\mathbf{j} = \mathbf{k}\cdot\mathbf{k} = 1$$

$$\mathbf{i} \times \mathbf{i} = \mathbf{j} \times \mathbf{j} = \mathbf{k} \times \mathbf{k} = 0$$

$$\mathbf{i} \times \mathbf{j} = -\mathbf{j} \times \mathbf{i} = \mathbf{k};$$

$$\mathbf{j} \times \mathbf{k} = -\mathbf{k} \times \mathbf{j} = \mathbf{i};$$

$$\mathbf{k} \times \mathbf{i} = -\mathbf{i} \times \mathbf{k} = \mathbf{j}.$$

VEERING WIND. Any clockwise change in wind direction is known as veering of the wind It is opposite to backing.

VELOCITY. (1) The time rate of change of position. Velocity is a vector quantity; a statement of a velocity therefore includes both a magnitude, expressed in units of length divided by time, and a direction relative to some frame of reference. The defining equation for instantaneous velocity is $\mathbf{v} = d\mathbf{x}/dt$, where **x** is the vector specifying position relative to an origin and t is the time. (Cf. **velocity, average.**) The origin is located with reference to an inertial frame, commonly axes fixed to the earth. (2) Sometimes loosely used to express magnitude only, i.e., synonymous with speed.

VELOCITY, ANGULAR. A quantity relating to rotational motion. While the use of the term "angular velocity" may be extended to any motion of a point with respect to any axis, it is commonly applied to cases of rotation. Its instantaneous value is defined as the vector, whose magnitude is the time rate of change of the angle θ rotated through, for example, $d\theta/dt$, and whose direction is arbitrarily defined as that direction of the rotation axis for which the rotation is clockwise. The usual symbol is ω or Ω.

The concept of angular velocity is most useful in the case of rigid body motion. If a rigid body rotates about a fixed axis and the position vector of any point P with respect to any point on the axis as origin is **r**, the velocity $\mathbf{r}$ of P relative to this origin is $\dot{\mathbf{r}} = \boldsymbol{\omega} \times \mathbf{r}$, where $\boldsymbol{\omega}$ is the instantaneous vector angular velocity. This indeed may serve as a definition of $\boldsymbol{\omega}$.

The average angular velocity may be defined as the ratio of the angular displacement divided by the time In general, however, this is not a vector, since a finite angular displacement is not a vector. The instantaneous angular velocity is more widely used.

Angular velocities, like linear velocities, are vectorially added, for example, if a top is spinning about an axis which is simultaneously being tipped over toward the table, the resultant angular velocity is the vector sum of the angular velocities of spin and of tipping (This enters into the theory of **precession.**) The derivatives of the **Eulerian angles** are sometimes very useful in describing the angular motion of a rigid body which has components of angular velocity about all its principal axes.

VELOCITY ANTIRESONANCE. See **antiresonance, velocity.**

VELOCITY, AVERAGE. Referring to a single material particle, the ratio of the change in the position vector to the time interval involved in the change. It is a vector quantity whose magnitude is usually called the average speed.

VELOCITY, CHARACTERISTIC, OF A MEDIUM. The phase velocity of an electromagnetic wave, $v = 1/\sqrt{\mu\epsilon}$.

VELOCITY, COEFFICIENT OF. See **coefficient of velocity.**

VELOCITY DIAGRAM (VELOCITY-MODULATION TUBES). See **Applegate diagram.**

VELOCITY, INSTANTANEOUS. See **velocity.**

VELOCITY, INSTANTANEOUS ANGULAR. See **velocity, angular.**

VELOCITY LEVEL. The velocity level, in decibels, of a sound is 20 times the logarithm to the base 10 of the ratio of the particle velocity of the sound to the reference particle velocity (see **velocity, particle**). The reference particle velocity should be stated explicitly. In many **sound fields** the particle velocity ratios are not proportional to the square root of corresponding power ratios and hence cannot be expressed in decibels in the strict sense; however, it is common practice to extend the use of the decibel to these cases.

VELOCITY, MAXIMUM. The maximum velocity for any given cycle is the maximum absolute value of the instantaneous velocity during that cycle.

VELOCITY, MAXIMUM ANGULAR. The maximum angular velocity for any given cycle is the maximum absolute value of the instantaneous angular velocity during that cycle. The unit is the radian per second

VELOCITY MICROPHONE. See **microphone, ribbon.**

VELOCITY-MODULATED OSCILLATOR. See **oscillator, velocity-modulated.**

VELOCITY-MODULATED TUBE. See **tube, velocity-modulated.**

VELOCITY MODULATION. The variation of the velocity of a beam of electrons as a periodic function of time.

VELOCITY OF LIGHT, MEASUREMENT OF. See (1) **Bradley, Aberration of Light.** (2) **Roemer, Astronomical Determination of Velocity of Light.** (3) **Fizeau, Toothed Wheel.** (4) **Foucault, Rotating Mirror.** (5) **Michelson, Rotating Mirror.** (6) **Rosa and Dorsey, Electromagnetic Computation of the Velocity of Light.**

VELOCITY OF LIGHT, VALUE OF. The best value in 1941, according to Raymond Birge, was 2.99776×10^{10} cm sec^{-1}.

VELOCITY OF SOUND. The velocity with which the **phase** of a **sound wave** is propagated. The velocity of sound in dry **air** is $(331.4\ M/S)\sqrt{T/273.16°K}$.

VELOCITY, PARTICLE. In a sound wave, the velocity of a given infinitesimal part of the medium, with reference to the medium as a whole, due to the sound wave. The commonly used unit is the centimeter per second. The terms "instantaneous particle velocity," "effective particle velocity," "maximum particle velocity," and "peak particle velocity" have meanings which correspond with those of the related terms used for **sound pressure.**

VELOCITY, PEAK. The peak velocity for any specified time interval is the maximum absolute value of the instantaneous velocity (see **velocity, instantaneous**) in that interval. The unit is the centimeter per second.

VELOCITY, PEAK ANGULAR. The peak angular velocity for any specified time interval is the maximum absolute value of the instantaneous angular velocity (see **velocity, instantaneous angular**) in that interval. The unit is the radian per second.

VELOCITY POTENTIAL OF SOUND. A scalar point function whose **gradient** gives the particle velocity at any point (see **velocity, particle**). Some authors, in analogy with the electric scalar potential, define the velocity potential function so that its negative gradient gives the particle velocity at any point.

VELOCITY, PRECESSIONAL. See **precession.**

VELOCITY PROFILE. The graphical representation of the variation with displacement normal to the general direction of flow of the mean flow velocity in a **shear** flow. For example, the velocity profile of laminar flow through a circular tube is parabolic.

VELOCITY, RELATIVE. The relative velocity of a point with respect to a reference frame is the time rate of change of a position vector of that point with respect to the reference frame.

VELOCITY RESONANCE. See **resonance, velocity.**

VELOCITY, ROOT-MEAN-SQUARE (OF A SYSTEM). The square root of the average of the square of the speed of the particles com-

posing the system This average is formed by summing the squares of the speed of each particle and dividing by the number of particles.

VELOCITY, SPIN. Angular velocity (see **velocity, angular**) about an axis fixed in space or in the spinning body.

VELOCITY, TERMINAL (FREE FALL IN AIR). When a particle falls in air or some other fluid medium which resists its motion with a force varying as some power of the speed, analysis shows that it approaches a limiting speed which can be calculated by equating the magnitude of the resisting force to the force of gravity.

VELOCITY, UNITS OF. The unit of velocity in the cgs system is the centimeter per second In the mks system it is the meter per second In the English system it is the foot per second For many practical purposes the mile per hour or kilometer per hour is used.

VELOCITY VARIATION. See **velocity modulation.**

VELOCITIES, ADDITION OF. See **addition of velocities.**

VENA CONTRACTA. The phenomenon of the contraction of the free **jet** of liquid issuing from a container through an **orifice.** Unless the orifice is a properly designed nozzle, the convergence of the flow approaching it continues beyond the exit section, and the final section of the jet is less than the exit section

VENTURI METER. A **flow meter** for liquids or gases utilizing the Venturi principle. A tapered constriction is placed in the pipe, and the pressure difference taken between a point in the pipe before the constriction begins, and a point in the throat, or the narrowest part of the constriction The observed pressure difference is a function of the rate of flow and may be calibrated or calculated to obtain flow rates For the principle of the Venturi meter, see **Bernoulli law.**

VERDET CONSTANT. A proportionality factor in an equation of the **Faraday effect,** the rotation of the plane of polarization of light by transparent substances in a magnetic field. In the relationship:

$$\alpha = \omega l H$$

α is the angle of rotation, l is the depth of the medium transversed by the light, H is the intensity of the magnetic field, and ω is the Verdet constant.

VERIFICATION. The process of automatically checking one data typing or recording process against another for the purpose of reducing the number of human errors in data transcription.

VERSINE. If θ is an angle, versine θ = vers $\theta = 1 - \cos\theta$.

VERTEX. Also called **apex.** (See **parabola; conical surface; polygon; polyhedron; node.**)

VERTEX POWER OF A LENS. The reciprocal of the **back focal length.**

VERTICAL BLANKING. In television, the interval during which the electron beam is being shifted from the bottom of the image back to the top, and the electron beam is prevented from reaching the screen.

VERTICAL CENTERING CONTROL. In television, an adjustment control for moving the image up or down on the viewing screen

VERTICAL HOLD CONTROL. See **control, vertical hold.**

VERTICAL ILLUMINATORS. It is difficult to illuminate the surface of an opaque substance, such as a metal, so that it can be observed with a high-power microscope To avoid this difficulty, certain microscopes are provided with a means by which light from a lamp may be passed down through the **objective lens** normal to the surface to be observed (Also called **metallographic microscope.**)

VERTICAL RECORDING. Disk recording in which the **modulation** is in the form of a variable-depth groove (Also sometimes called **hill-and-dale recording.**)

VERTICAL RETRACE. In television, the return path of the electron beam during the **vertical blanking** interval.

VERTICALLY POLARIZED WAVE. See **wave, vertically polarized.**

VERY HIGH FREQUENCY. The band of frequencies between 30 and 300 megacycles.

VERY LOW FREQUENCY. The band of frequencies between 10 and 30 kilocycles.

VESTIGIAL SIDEBAND. See **sideband, vestigial.**

VESTIGIAL-SIDEBAND TRANSMISSION. See **transmission, vestigial-sideband.**

VESTIGIAL-SIDEBAND TRANSMITTER. See **transmitter, vestigial-sideband.**

VFO. Abbreviation for variable frequency oscillator.

VHF. Abbreviation for **very high frequency,** the band of frequencies between 30 and 300 megacycles.

VIBRATING CONTACTER. A device which periodically makes and breaks contact in a cyclic fashion, used for converting d-c signals to a-c signals. (It is also called a **vibrator** or **chopper.**)

VIBRATION(S) AND WAVES. These terms are used in very broad senses and apply to a large variety of phenomena and processes. "Vibration" commonly refers to a to-and-fro motion, its meaning is often broadened to include any periodic physical process, such, for example, as a cyclic variation in electric or magnetic field intensity. When an elastic body is deformed and released, it is in general set into oscillation such that the displacement of any particle from its equilibrium position is a more or less complicated harmonic function of the time. The vibration may or may not be symmetrical with respect to the neutral position; in any case the maximum displacement is called the amplitude of the vibration. By analogy, the same terms and the same analysis are applied to vibrations of any type.

If a vibratory disturbance occurs at any point in a medium having sufficient continuity to transmit displacements from one part to another, a train of waves is propagated outward from the seat of the disturbance. The speed of propagation depends upon the closeness of coupling between adjacent particles of medium and the consequent magnitude of the restoring forces; and upon whatever reaction of the medium corresponds to mechanical inertia. In some cases also the speed varies with the frequency, as with light in a material medium. In any case the wavelength, viz., the distance traversed during a complete vibration period, is related to the frequency of vibration and the speed of propagation by the simple equation $v = \nu\lambda$ in which v is the speed, ν the frequency, and λ the wavelength. Thus, if sound waves of frequency 250 vibrations per sec are traveling with a speed of 1000 ft per sec, the wavelength is 4′. In case the vibrations are of complex character and the different components travel with different speeds, the resulting "wave group," traveling with its characteristic **group velocity,** may be very sharply defined and may thus constitute a "wave packet," resembling a single pulse or unrepeated wave.

The theorem of Fourier states that any vibration or wave train, however complex, can be resolved into simple harmonic components of various amplitudes and frequencies and in various phases. Of these components, the one of lowest frequency (and in the case of elastic vibrations, usually of greatest amplitude) is the "fundamental"; the others are "overtones."

The character of a wave process may be described mathematically by means of a **wave equation** which specifies the condition at any point of the wave field in terms of the position and of the time; or graphically by one or more **wave form** curves, of which the ordinates represent the periodically variable displacements at any point, and the abscissas the time

VIBRATION, FUNDAMENTAL MODE OF. The mode of vibration of a system (see **vibration, normal mode of**) which has the lowest frequency.

VIBRATION GALVANOMETER. See **galvanometer, vibration.**

VIBRATION METER (VIBROMETER). An apparatus for the measurement of displacement, velocity, or acceleration of a vibrating body.

VIBRATION, NORMAL MODE OF. A characteristic distribution of vibration amplitudes among the parts of the system, each part of which is vibrating freely at the same frequency. Complex free vibrations are combinations of these simple vibration forms. (See **oscillator, coupled.**)

VIBRATION-ROTATION SPECTRUM. A spectrum in the infrared portion of the electromagnetic **spectrum** which is produced by vibrational and rotational transitions within a molecule. Such spectra are useful in calculating force constants, and other molecular constants. (See **spectrum, infrared.**)

VIBRATIONAL ENERGY OF DIATOMIC MOLECULES. In the *Report on Notation for Spectra of Diatomic Molecules,* Mullikan, *Phys. Rev.* **36,** 623 (1930), the vibrational energy E_v is defined as the difference between the energy of a molecule idealized just to the extent of making $E_r = 0$ and the energy of a further idealized molecule obtained by the following imaginary process: the vibration of the nuclei is gradually stopped without placing any new constraint on the electron motions, in a way such as might be realized by leaving the charges of the nuclei unchanged but gradually increasing the masses until they are infinite.

VIBRATIONAL PARTITION FUNCTION. The contribution to the total **partition function** of molecules associated with their vibrational energy.

VIBRATIONAL SUM RULE. The sums of the band strengths of all bands with the same upper or the same lower state are proportional to the number of molecules in the upper and lower state, respectively The band strength is the emission intensity divided by ν^4 or the absorption intensity divided by ν. In absorption, in place of the intensity, the integrated absorption coefficient may be used. In emission, the intensities used must, if necessary, be corrected for **self-absorption.** This rule is valid only if the electronic transition moment is a constant for all vibrational transitions that give an appreciable contribution to the sum.

VIBRATO. A musical embellishment which depends primarily upon periodic variations of **frequency** which are often accompanied by variations in **amplitude** and **wave form.** The quantitative description of the vibrato is usually in terms of the corresponding modulation of frequency, amplitude, wave form, or all three.

VIBRATOR. A magnetically-operated, switch mechanism used to "chop" d-c into essentially square waves of a-c for the purposes of **transformation.** Two types are encountered in radio service; non-synchronous and synchronous. The non-synchronous vibrator merely performs the d-c to a-c conversion as mentioned above, while the synchronous vibrator is equipped with an additional set of contacts operating in synchronism with the first. The second switch set is used to convert the a-c, after transformation, back to d-c.

VIBRATRON. A high **Q resonator.**

VIBROTRON. A movable-anode **triode.**

VICTOR MEYER METHOD FOR VAPOR PRESSURE. A small, stoppered, glass vessel containing a weighed amount of liquid is dropped into a large bulb at the bottom of a long vertical tube The bulb and part of the tube are surrounded by a constant-temperature bath, whose temperature is higher than the boiling point of the liquid, but need not be known. The liquid vaporizes, forcing off the stopper, and the vapor displaces an equal volume of air from the large bulb This displaced air is led away, and its volume measured, e g., by a gas burette, or by collecting it in an inverted graduated vessel filled with water, over a pneumatic trough Thus, knowing the weight and volume, the vapor density can be found. The method is simple and rapid, and is accurate to about 5%. Modifications have been made for low pressures and high temperature, e g , by Matheson and Maass, Mousching and Meyer and Nernst.

VIDEO. A term pertaining to the bandwidth and spectrum position of the signal resulting from television **scanning.** In current usage, video means a bandwidth of the order of megacycles, and a spectrum position that goes with a d-c carrier.

VIDEO FREQUENCY. See **video.**

VIDEO-FREQUENCY AMPLIFIER. See **amplifier, video-frequency.**

VIDEOTRON. A **monoscope.**

VIDICON. A camera tube (see **tube, camera**) with a photoconductive **mosaic.** In other aspects, the tube is similar to an **orthicon.**

VIEW FINDER. An auxiliary optical or electronic device attached to a television camera which enables the operator to see the scene as the camera sees it.

VIGNETTING EFFECT. The falling-off in **brightness** towards the margin of an illuminated field, due to the mutilation of the more oblique bundles of light by the combined effects of **diaphragm** and lens **aperture.** This is a source of trouble in photographic objectives when they are used at large apertures, or close to the limit of their fully-illuminated fields.

VILLARI EFFECT. See discussion of **magnetostriction.**

VIRGIN NEUTRONS. Neutrons from any source, before they make a collision.

VIRIAL OF A SYSTEM. If in a system of n particles confined to a finite region of space whose position vectors with respect to a given origin are $\mathbf{r}_i$ the resultant force on the ith particle is $\mathbf{F}_i$, the virial of the system is defined to be

$$\overline{-\frac{1}{2}\sum_{i=1}^{n} \mathbf{r}_i \cdot \mathbf{F}_i}.$$

The bar over the sum refers to a time average over a time interval long compared with the time taken by a particle to traverse the region in which the particles are confined. It is understood that not only are the magnitudes of the position vectors $\mathbf{r}_i$ bounded, but that the same is true of the velocities of the particles. According to the virial theorem the virial of the system is equal to the average kinetic energy of the system.

VIRIAL THEOREM. See **virial of a system.**

VIRTUAL CATHODE. See **cathode, virtual.**

VIRTUAL ENTROPY. The entropy of a system neglecting the contribution due to nuclear spin, which is generally a factor independent of temperature and does not contribute to heat capacities This also excludes entropy of mixing of different isotopic forms, which remains virtually the same in a chemical reaction. (Also known as **practical entropy.**)

VIRTUAL HEIGHT. The apparent height of an ionized layer determined from the time interval between the transmitted signal and the **ionospheric echo** at vertical incidence, assuming that the velocity of **propagation** is the velocity of light in a vacuum over the entire path.

VIRTUAL LEVEL, VIRTUAL STATE. (1) A quasi-stationary energy level or state of a compound nucleus, characterized by a lifetime long compared with the **transit times** of the nucleons across nuclear dimensions at energies corresponding to the excitation in question; therefore, very often a **resonance level.** (2) A term that has frequently been used to refer to the so-called "unbound singlet state" of the deuteron. However, such a usage gives this "state" undue importance, for it does not actually exist; its invention arose from the merely formal possibility of calculating a fictitious negative binding energy of the singlet neutron-proton system that would give the same scattering length as is observed in neutron-proton scattering.

VIRTUAL PROCESS. Process which may be pictured as the emission of a particle or quantum followed so quickly by its absorption or further interaction that the energy and momentum of the particle in this intermediate state are ill-defined Each such process corresponds to a term in the series expansion of the **Hamiltonian** for the whole process and may be represented on a **Feynman diagram.**

VIRTUAL QUANTUM. In second and higher order **perturbation theory,** a **matrix element** connecting an initial state with a final state involves intermediate states in which energy is not conserved. A quantum or photon in such an intermediate state is termed a virtual quantum. Thus the self-energy of an electron (due to the electromagnetic field) is pictured as arising from the continual emission and reabsorption by the electron of virtual quanta. Similarly the **Coulomb energy** between two electrons may be pictured as arising from the emission of virtual quanta by one of the electrons and their absorption by the other.

VIRTUAL TEMPERATURE. Air free from water vapor has a certain density for fixed temperature and pressure If, however, some water enters the air as vapor and the pressure is held constant, the density will decrease slightly because the molecular weight of water is 18, compared to 28 97 for air. Also, if the air remains water-free and the temperature increases slightly, the density will also decrease. Virtual temperature of air is that

temperature required to maintain its density constant if its water-vapor content is removed. Virtual temperature in air containing water is always greater than existing temperature.

$$T_v = \frac{T}{1 - 0.379p/P}$$

where T_v is the virtual temperature, t is the existing temperature, p is the vapor pressure of water vapor, and P is the total pressure of the air.

VIRTUAL WORK PRINCIPLE. See **equilibrium of forces on rigid body; least energy principle.**

VISCOSIMETER. An instrument for the measurement of **viscosity,** usually a practical instrument designed to measure relative values and not suitable for absolute measurements.

VISCOSITY. The phenomenon of the generation of stresses in a fluid by the distortion of fluid elements by the flow The stresses act to oppose the distortion and to dissipate energy. The term is usually taken to mean a Newtonian viscosity. (See **fluid, Newtonian; fluid, viscous;** and immediately following entries.)

VISCOSITY, COEFFICIENT OF. If the **stress tensor** in an isotropic fluid is a linear function of the rate of **strain,** then

$$p_{ij} = \eta\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) - \left(\eta'\frac{\partial u_i}{\partial x_i} + p\right)\delta_{ij}$$

where p_{ij} is the stress tensor, $\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)$ is the rate of strain tensor, p is the hydrostatic pressure, δ_{ij} is the substitution tensor ($= 1$, if $i = j$; $= 0$ if $i \neq j$).

The constant coefficient, η, is the ordinary coefficient of viscosity, and the other one, η', is the second coefficient of viscosity. The second coefficient describes effects that depend on volume **dilatation.**

VISCOSITY, EYRING TREATMENT OF. See **Eyring treatment of viscosity.**

VISCOSITY, INTRINSIC. The value obtained by extrapolating, to zero concentration, the ratio of the specific viscosity of a solution to the concentration of the solute.

VISCOSITY, KINEMATIC. The fluid viscosity divided by the fluid density. It measures the kinematic effect of the viscosity, that is, the accelerations of the fluid arising from a given distortion. It may be regarded as the diffusion coefficient for **vorticity** and, to a lesser extent, for **momentum.** Typical values of the kinematic viscosity, denoted by ν, are

Water (20°C)	$\nu = 0.0100\ \text{cm}^2\ \text{sec}^{-1}$
Mercury (20°C)	$\nu = 0.00118\ \text{cm}^2\ \text{sec}^{-1}$
Glycerine (20°C)	$\nu = 6.8\ \text{cm}^2\ \text{sec}^{-1}$
Air (20°C, 760 mm)	$\nu = 0.152\ \text{cm}^2\ \text{sec}^{-1}$

The cgs unit of kinematic viscosity is sometimes called the **stoke.**

VISCOSITY, MEASUREMENT OF. (a) Absolute methods: (1) Stokes law methods. These involve measuring the rate of fall under gravity of a small sphere in the liquid whose viscosity is required. A variant is to measure the rate of rise of a small glass bulb. In either case, the viscosity η is given by

$$\eta = \frac{2gr^2(\rho - \rho_l)}{9V}$$

where r is the radius of the sphere or bulb, ρ is the density of the sphere or bulb, ρ_l is the density of the liquid, V is the rate of fall or rise.

(2) Capillary tube methods. These methods apply the **Poiseuille equation** to the measurement of viscosity. The flow through a tube of known internal radius and length is measured for a known pressure difference between the ends.

(3) Rotating cylinder methods. The **torque** transmitted to a stationary inner cylinder when the outer one is rotated at constant speed is given by a simple equation involving the viscosity, provided the speed of rotation is not too high. This method is well-suited for precision measurement, as end effects may be eliminated by guard rings.

(4) Oscillating disc method. A disc oscillating in a plane parallel and close to a plane surface undergoes a damping due to the viscosity of the intervening fluid. Knowing the dimensions of the apparatus and the rate of damping, the viscosity may be calculated.

(b) Relative methods: Most of the absolute methods have been applied in simplified

form to the measurement of relative viscosity, the apparatus being calibrated by the use of a fluid of known viscosity. For example, the Engler and Saybolt viscosimeters use the time taken for a sample of liquid to flow past a constriction in a U-tube as a measure of the viscosity.

VISCOSITY OF GASES. A theoretical treatment similar to that used for the **thermal conductivity of gases** gives the relation

$$\eta = \frac{1}{3}\rho\bar{c}\lambda$$

where η is the viscosity, ρ the density, $\bar{c}$ the mean molecular velocity, and λ the mean free path. This formula indicates that the viscosity should be independent of the density (and therefore pressure), since $\rho \propto 1/\lambda$, and should increase as the square root of the absolute temperature T, since $\bar{c} \propto \sqrt{T}$. This is found to be approximately true except at high and low pressures. Measurement of η may be used to deduce values of the mean free path and hence molecular diameter, with the introduction of numerical factors given by more refined theory. (See **thermal conductivity of gases, theoretical.**)

VISCOSITY, RELATIVE. (1) The ratio of the **viscosity** of a solution to the viscosity of the pure solvent. (2) The ratio of the viscosity of a liquid to that of another liquid taken as a standard.

VISCOSITY, SPECIFIC. The specific **viscosity** of a solution is the ratio of the difference between the viscosities of the solution and of the pure solvent to the viscosity of the pure solvent.

VISCOSITY, THEORIES OF. (1) Gas kinetic theory. Interaction between the molecules is supposed negligible except for the comparatively short time occupied in molecular collisions. The development of a **shear stress** in a velocity **gradient** is caused by the diffusive movements of molecules along the gradient, and the kinematic viscosity (see **viscosity, kinematic**) is of the same order of magnitude as the self-diffusion coefficient, of order $\frac{1}{3}\,\bar{c}\,\lambda$ ($\bar{c}$, the **mean molecular velocity,** λ, the **mean free path**).

(2) Imperfect solid theory. The yielding of a liquid to a shear stress is compared with the **creep** of crystalline solids at high temperatures. The rate of creep for a given stress depends on yielding along grain boundaries, which requires an **activation energy** derived from the thermal energy. The **fluidity** then increases with temperature, roughly as $e^{W/kt}$, where W is activation energy. The possibility of extending this theory to liquids depends on the existence of **short range order,** or of **clusters** of liquid molecules corresponding to crystal grains.

VISCOSITY, UNITS OF. The common metric unit of viscosity is the **poise,** which is equal to 1 dyne-cm $^{-2}$ sec. There is also the centipoise (0.01 poise). Another metric unit is the kg-wt-cm^{-2} sec. English units are the lbm ft^{-1} sec^{-1} and the lbf ft^{-2} sec. Many specialized units are used in engineering practice, related to specific instruments for the measurement of viscosity, e.g., Engler degree, Saybolt second.

VISIBLE SPEECH. An electronic method of changing spoken words into visible patterns that someone can learn to read.

VISIBILITY. That greatest distance toward the horizon at which an unaided normal eye can clearly distinguish prominent objects without aid of optical devices. In measuring visibility, officially, it is necessary that the value given exist over more than one-half the horizon.

VISIBILITY FACTOR. For radiation of a given wavelength, the ratio of the **luminous flux** at that wavelength to the corresponding **radiant flux.** This factor depends on the sensitivity of the eye to light of different wavelengths. It varies from zero at wavelengths less than about 4000 Å, through a maximum of about 660 **lumens** per watt at around 5500 Å, to zero again for wavelengths greater than about 7500 Å. (Also called **luminosity function** and **luminous efficiency.**)

VISIBILITY (OF FRINGES). The visibility of fringes is defined as

$$\frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}}$$

where $I_{\max}$ is the maximum intensity of the fringe system and $I_{\min}$ is the minimum intensity.

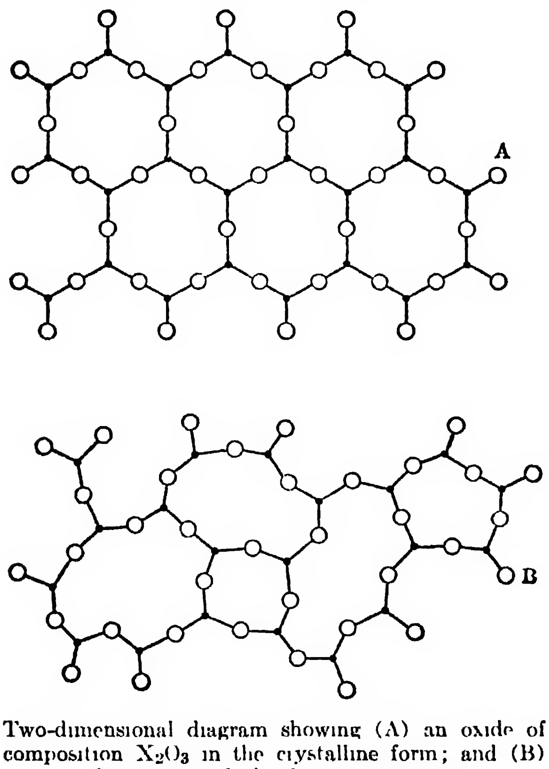
VISION, PERSISTENCE OF. The sensation in the **retina** does not cease at once when the stimulus is removed. For a brightness of

about a **candle** per square meter, the critical frequency beyond which no **flicker** may be detected is about 30 times per second. The limit, however, depends greatly on the conditions of observation, and particularly on the **brightness** alternation.

VISUAL TRANSMITTER. See **transmitter, visual.**

VISUAL TRANSMITTER POWER. See **power, visual transmitter.**

VITREOUS STATE. When certain liquids are cooled fairly rapidly, crystals do not form at a definite temperature, but the viscosity of the liquid increases steadily until a glassy substance is obtained. A **glass** may be thought of as a disordered amorphous solid, or as a supercooled liquid which only **devitrifies** into the crystalline state after extremely long standing. Glasses are optically isotropic, which explains their value in optical instruments. The property of forming a glass is possessed particularly by the oxides of silicon, boron, germanium, arsenic, phosphorus, etc.,



Two-dimensional diagram showing (A) an oxide of composition X_2O_3 in the crystalline form; and (B) the same oxide in the vitreous state

and by many organic compounds, especially those containing several hydroxyl groups per molecule. (See figure.)

VLF. Abbreviation for **very low frequency.**

VOCODER. An instrument for the production of synthetic speech, employing recorded voice signals to actuate the system instead of the mechanical keys used by the **voder.**

VODAS. The name applied to a two-way, radio-telephone transmission system employing the same frequency for transmission and reception. Voice-operated relays prevent simultaneous operation of transmitter and receiver.

VODER. An instrument for the production of synthetic speech, employing a series of electron tubes, controllable by mechanical keys, to vary the frequency, intensity, quality, duration, growth and decay of tones.

VOGAD. Abbreviation for voice-operated gain-adjusting device. A **volume compressor** or **expandor.** (See **amplifier, volume-limiting.**)

VOGEL-COLSON-RUSSELL EFFECT. See **Russell effect.**

VOICE COIL. A coil of wire wound on a cylindrical paper form and attached to the throat of a direct radiator loudspeaker (see **loudspeaker, direct radiator**) or microphone and used, in conjunction with a magnetic field, to drive the cone of the loudspeaker.

VOICE FREQUENCY. See **audio frequency.**

VOICE MECHANISM. The entire system for the production of human speech. It consists of three parts: the lungs and associated muscles for maintaining a flow of air, the larynx for converting the steady air flow into a periodic modulation, and the vocal cavities of the pharynx, mouth and nose, which vary the harmonic content of the output of the larynx.

VOIGT EFFECT. When a strong magnetic field is applied to a vapor through which light is passing perpendicular to the field, **double-refraction** occurs. This phenomenon is associated with the **Zeeman effect.**

VOIGT NOTATION. A notation used in the theory of **elasticity,** whereby the **elastic constants** and **elastic moduli** are labeled according to a scheme in which the pairs of letters xx, yy, zz, yz, zx, and xy are replaced by the numbers 1, 2, 3, 4, 5, and 6, respectively.

Thus the elastic constants are the coefficients s_{11}, s_{12}, etc., in the following equations between the strains e_{xx}, e_{yy}, etc., and the stresses X_x, Y_y, etc.

$$\begin{aligned}
e_{xx} &= s_{11}X_x + s_{12}Y_y + s_{13}Z_z + s_{14}Y_z \\
&\quad + s_{15}Z_x + s_{16}X_y; \\
e_{yy} &= s_{21}X_x + s_{22}Y_y + s_{23}Z_z + s_{24}Y_z \\
&\quad + s_{25}Z_x + s_{26}X_y; \\
e_{zz} &= s_{31}X_x + s_{32}Y_y + s_{33}Z_z + s_{34}Y_z \\
&\quad + s_{35}Z_x + s_{36}X_y; \\
e_{yz} &= s_{41}X_x + s_{42}Y_y + s_{43}Z_z + s_{44}Y_z \\
&\quad + s_{45}Z_x + s_{46}X_y; \\
e_{zx} &= s_{51}X_x + s_{52}Y_y + s_{53}Z_z + s_{54}Y_z \\
&\quad + s_{55}Z_x + s_{56}X_y; \\
e_{xy} &= s_{61}X_x + s_{62}Y_y + s_{63}Z_z + s_{64}Y_z \\
&\quad + s_{65}Z_x + s_{66}X_y.
\end{aligned}$$

The elastic moduli are the coefficients c_{11}, c_{12}, etc., in the inverse relations, i.e.,

$$\begin{aligned}
X_x &= c_{11}e_{xx} + c_{12}e_{yy} + c_{13}e_{zz} + c_{14}e_{yz} \\
&\quad + c_{15}e_{zx} + c_{16}e_{xy}; \\
Y_y &= c_{21}e_{xx} + c_{22}e_{yy} + c_{23}e_{zz} + c_{24}e_{yz} \\
&\quad + c_{25}e_{zx} + c_{26}e_{xy}; \\
Z_z &= c_{31}e_{xx} + c_{32}e_{yy} + c_{33}e_{zz} + c_{34}e_{yz} \\
&\quad + c_{35}e_{zx} + c_{36}e_{xy}; \\
Y_z &= c_{41}e_{xx} + c_{42}e_{yy} + c_{43}e_{zz} + c_{44}e_{yz} \\
&\quad + c_{45}e_{zx} + c_{46}e_{xy}; \\
Z_x &= c_{51}e_{xx} + c_{52}e_{yy} + c_{53}e_{zz} + c_{54}e_{yz} \\
&\quad + c_{55}e_{zx} + c_{56}e_{xy}; \\
X_y &= c_{61}e_{xx} + c_{62}e_{yy} + c_{63}e_{zz} + c_{64}e_{yz} \\
&\quad + c_{65}e_{zx} + c_{66}e_{xy}.
\end{aligned}$$

VOLATILE. (1) Having a low boiling or subliming temperature at ordinary pressure; in other words, having a high vapor pressure, as ether, camphor, naphthalene, iodine, chloroform, benzene, or methyl chloride. (2) In computer terminology, the attribute of a memory device that information is lost in the event of a power interruption.

VOLATILITY PRODUCT. The product of the concentrations of two or more ions or molecules that react to produce a volatile substance. The volatility product is analogous to the **solubility product,** except that, when it is exceeded, the substance escapes from the system by volatilization rather than precipitation. As with the solubility product, if any of the reacting ions or molecules have a numerical coefficient greater than one, then the concentration term of that ion or molecule is raised to the corresponding power.

VOLT. A unit of electrical potential difference, abbreviation V or v. (1) The absolute volt is the steady potential difference which must exist across a conductor which carries a steady current of one absolute ampere and which dissipates thermal energy at the rate of one watt. The absolute volt has been the legal standard of potential difference since 1950. (2) The International volt, the legal standard prior to 1950, is the steady potential difference which must be maintained across a conductor which has a resistance of one International ohm and which carries a steady current of one International ampere.

1 Int. volt = 1.000330 Abs. volts.

VOLT-AMPERE. The product of effective voltage (see **voltage, effective**) and effective current (see **current, effective**) in an alternating current load is its volt-ampere input. The real component $EI \cos \phi$ is the real power input, measured in watts. (ϕ is the phase angle between the voltage and the current.) The reactive component $EI \sin \phi$ is the "reactive power" and is measured in "vars" (volt-ampere, reactive).

VOLT-SECOND AREA. That area under the curve of supply voltage vs. time which corresponds to the flux change in the **core** of a **saturable reactor.**

VOLTA LAW. See **contact potential difference.**

VOLTAGE. **Electromotive force** or difference of **potential** measured in volts.

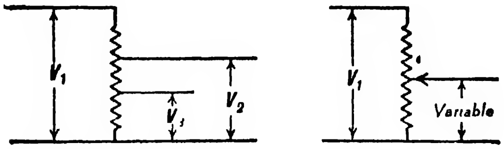
VOLTAGE, AMPLIFICATION. See **amplification, voltage.**

VOLTAGE ATTENUATION. The ratio of the magnitude of the voltage across the input of a **transducer** to the magnitude of the voltage delivered to a specified load impedance connected to the transducer. If the input and/or the output voltage consist of more than one component, such as multifrequency signal or noise, then the particular components used and their weighting should be specified. By custom this attenuation is often expressed in decibels by multiplying its common logarithm by 20.

VOLTAGE, COMPOSITE CONTROLLING. The voltage of the anode of an equivalent **diode,** combining the effects of all individual electrode voltages in establishing the space-charge-limited current.

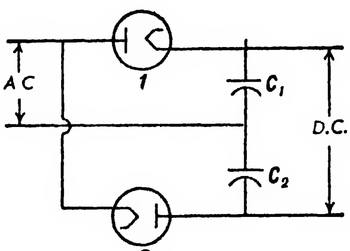
VOLTAGE, DECOMPOSITION (DISCHARGE POTENTIAL). The minimum e.m f. required to cause steady electrolysis in a solution. In normal solutions of sulfuric acid and zinc sulfate it is 1.67 volts and 2.35 volts, respectively.

VOLTAGE DIVIDER. The ordinary three-terminal resistance is often used as a voltage divider. If no current is taken from the intermediate tap the voltages will be in proportion to the resistance included between the taps. In many applications a potentiometer is used as a voltage divider so the voltage may be adjusted by varying the position of the tap. If current is drawn from the tap the exact distribution of the voltage is altered but the total voltage applied across the divider is still



divided between the various sections The figure shows some typical arrangements

VOLTAGE DOUBLER. A connection of condensers and rectifiers across an a-c source which gives a d-c output voltage approximately twice that of the normal connection. The exact value of the output voltage depends upon the load and for very high loads may not even approach the theoretical double value. A circuit is shown in the figure On



one half-cycle C_1 charges through tube 1 and on the other half-cycle C_2 charges through tube 2, the polarities being as shown on the diagram. It is seen then that the output voltage is the sum of the two condenser voltages.

VOLTAGE FEEDBACK RATIO, TRANSISTOR. See **transistor parameter h_{12}.**

VOLTAGE-GAIN EQUATION. See **voltage amplification.**

VOLTAGE REGULATION. Automatic voltage regulators are relied upon for maintenance of constant **generator** voltage. Alternator-voltage regulators have, for all practical purposes, become limited to four distinct types, the vibrating, the magnetic, the rheostatic, and electronic. D-c regulators are usually rheostatic.

VOLTAGE REGULATOR TUBE. See **regulator tube.**

VOLTAGE, INVERSE PEAK. The peak voltage which may be safely impressed across an electron **tube** in the inverse direction, i e., with the **anode** negative and the **cathode** positive If this voltage rating of the tube is exceeded there is danger of the tube conducting in the inverse direction (see **arc back**) and thus ceasing to act as a **rectifier.** In certain circuits this type of conduction will result in currents of destructive magnitude.

VOLTAGE SATURATION. The condition which exists in a thermionic electron tube when the **space current** (for a given cathode temperature) cannot be increased by further increase of electrode voltages (neglecting the increase due to the **Schottky effect**) The tube is said to be temperature limited when operating in the region of voltage saturation

VOLTAGE, STARTING. For a **counter tube,** the minimum voltage that must be applied to obtain counts with the particular circuit with which it is associated

VOLTAGE, SWEEP. The voltage producing the horizontal deflection (sweep) in a cathode-ray **oscillograph,** usually a linear, sawtooth voltage Also, the horizontal and vertical "sweep voltages" used to generate the **scanning raster** in a television receiver

VOLTAGE, TIME-BASE. The **sweep voltage** applied to a **cathode-ray tube.**

VOLTAIC. Furnishing an **electric current.**

VOLTAIC CELL. See **cell, voltaic.**

VOLTAIC CURRENT (VOLTAIC ELECTRICITY. VOLTAISM). Terms formerly used to designate the electricity furnished by the voltaic cell, before the identity of the electricity from different sources was recognized.

VOLTAMETER. A **coulometer.**

VOLTERRA DISLOCATION. A model of a **dislocation** obtained by taking a ring of material, cutting it, displacing the cut surfaces, and rejoining them.

VOLTERRA EQUATION. **Integral equation** of the first or second kind similar to **Fredholm's equation,** except that the upper limit of integration is x, the independent variable. It may be **homogeneous** or **inhomogeneous.** An example of the former type and of the first kind is the **Abel equation.**

VOLTMETER(S). The usual instruments of this class differ from **ammeters** used on the same type of service in only one essential respect: they are of very high resistance. Therefore, when connected across the terminals between which the voltage is to be measured, they take very little current and cause but a very slight drop in the potential difference. The current through the voltmeter is proportional to the voltage, and the scale may therefore be graduated to read directly in volts. Instruments are made which, with the proper change in connections, serve either as voltmeters or ammeters, the scale having two graduations. For high voltages, the voltmeter is placed in series with a large resistance, called a multiplier, so that the potential difference between its terminals is a known fraction of the voltage under test.

There are electrostatic voltmeters which may be used to measure electrostatic potentials of thousands of volts A common form resembles a gold-leaf **electrometer** of large size, but with a brass pointer swinging on a scale in place of the gold-leaf.

VOLTMETER, AVERAGE. A meter whose indication is proportional to the half-wave average value or to the full-wave average absolute value of an alternating voltage. The more generally used full-wave voltmeter employs some form of **full-wave rectifier,** as its name implies, and does not have **turn-over** error as does the half-wave circuit. The instruments are frequently calibrated in terms of the rms value of an assumed sinusoidal voltage.

VOLTMETER, CORONA. A meter which uses as an indicator the known relationship between the magnitude of voltage, electrode spacing, and the start of a **corona discharge.**

VOLTMETER, ELECTRODYNAMIC. See **electrodynamometer.**

VOLTMETER, ELECTRONIC, PEAK-READING. Essentially some form of half-wave **rectifier** circuit which charges a capacitor to either the positive or negative peak of an electrical wave. Usually a d-c vacuum-tube voltmeter is used to measure the average value of their capacitor voltage. The meter is subject to "turn-over" error in that it will give different readings, depending upon the actual connection employed, when measuring nonsinusoidal waves with different positive and negative peaks. The voltmeters are frequently calibrated in terms of the rms value of an assumed sinusoidal voltage.

VOLTMETER, ELECTROSTATIC. See **electrometer.**

VOLTMETER, INVERTED. See **amplifier, step-down.**

VOLTMETER, MOVING-IRON. A cheap, rugged, insensitive type of instrument much used at power frequencies. A soft-iron vane is deflected by the magnetic field of a coil across which the unknown voltage is impressed. The meter has an approximately **square-law** response.

VOLTMETER, PEAK-TO-PEAK. Essentially two peak-reading voltmeters used together in order to produce a reading proportional to the voltage difference separating the positive and negative peak of an electric wave. (See **voltmeter, electronic, peak-reading.**)

VOLTMETER, RECTIFIER. A d-c meter movement, combined with a small **bridge rectifier** to make it respond to a-c.

VOLTMETER, SLIDE-BACK. A **voltmeter** (usually electronic) in which the unknown voltage is compared to a calibrated, adjustable voltage-source, the calibrated adjustable source being adjusted until equal to the unknown

VOLTMETER, THERMOCOUPLE. A combination of a sensitive, low-resistance **galvanometer,** a **thermocouple** element, and a heating wire across which the voltage is impressed. (See **vacuum thermocouple (1).**)

VOLTMETER, VACUUM-TUBE. Commonly a very high input impedance **volt-**

meter, utilizing the power **gain** of **a vacuum tube** for operating a suitable meter movement without loading the source of the voltage to be measured.

VOLTMETER, VACUUM TUBE, RESISTANCE MEASUREMENTS WITH. Since a vacuum-tube voltmeter can have a very high input impedance, it provides a simple means of measuring resistance by comparison with a fixed resistance The unknown resistance is connected in series with a fixed resistance and a fixed voltage. The voltage appearing across the unknown is a simple function of the unknown resistance, and the voltmeter scale can be made direct reading in ohms.

VOLUME. (1) The space occupied by any body. It is definite for any specific temperature and pressure. The metric units of volume are the cubic centimeter and the liter. The volume of one **gram molecule** of a gas at standard temperature and pressure is about 22.4 liters

(2) The **volume** of a **parallelepiped** is often represented as a scalar **triple product** of three vectors, the edges of the solid. In **calculus,** the volume of a solid may be found by means of **definite integrals,** as follows: (a) If a plane perpendicular to the X-axis at a distance x from the origin cuts, from a given solid, a section whose area is $A(x)$, then the volume of that part of the solid between $x = a$ and $x = b$ is given by the definite integral

$$V = \int_a^b A(x)dx.$$

(b) Suppose the solid is that part of a right circular cylinder included between the XOY-plane and the surface $z = f(x,y)$, then its volume is given by the definite **double integral**

$$V = \int_{a_1}^{a_2}\int_{b_1}^{b_2} f(x,y)dxdy$$

where the base of the cylinder is bounded by the curves $x = a_1$, $x = a_2$, $y = b_1$, $y = b_2$. (c). If the solid is divided into volume elements, $d\tau = dxdydz$ which are right prisms with base $dxdy$ and altitude dz, the volume of the solid is given by the **triple** definite **integral**

$$V = \int_{x_1y_1z_1}^{x_2y_2z_2} dxdydz$$

where the limits are determined by the boundary of the given solid. **Vector** methods are often useful (see **integral, volume**).

(3) The magnitude, as measured on a standard volume indicator, of a complex voice-frequency wave in an electric circuit. The volume is expressed in **volume units.** In addition, the term "volume" is used loosely to signify either the intensity of a sound or the magnitude of an electrical wave.

VOLUME ADVANTAGE FACTOR. In reactor theory, the ratio

$$\frac{\sigma_{a0}}{(\sigma_{a0})_{eff}}$$

where σ_{a0} is the absorption **cross section** of the fuel for neutrons at a given energy, and $(\sigma_{a0})_{eff}$ is a function of the **absorption cross section** and the **scattering cross section.**

VOLUME, CRITICAL. The volume occupied by one gram of a liquid or gaseous substance at its **critical temperature** and **critical pressure.**

VOLUME ELASTICITY OR BULK MODULUS. For an elastic substance the negative of the ratio of the excess pressure producing compression to the fractional change in volume (or volume dilatation). (See **bulk modulus.**)

VOLUME INDICATOR. A standardized instrument having specified electrical and dynamic characteristics and read in a prescribed manner, for indicating the volume of a complex electric wave such as that corresponding to speech or music. The reading in **volume units** is equal to the number of decibels above a reference level The sensitivity is adjusted so that the reference level, or zero volume units, is indicated when the instrument is connected across a 600-ohm resistor in which there is dissipated a power of 1 milliwatt at 1,000 cycles per second.

VOLUME-LIMITING AMPLIFIER. See **amplifier, volume-limiting.**

VOLUME, MOLECULAR (GRAM-MOLECULAR VOLUME). The volume occupied by a **gram molecule** of any substance. It is equal to the product of the **specific volume** by the **molecular weight.**

VOLUME, REFERENCE. That magnitude of a complex electric wave, such as that cor-

responding to speech or music, which gives a reading of zero **volume units** on a standard **volume indicator.**

VOLUME, STANDARD. The volume occupied by one **gram molecular weight** of a gas at 0°C and a pressure of 1 standard atmosphere. (See **atmosphere, standard (1).**)

VOLUME UNIT (VU). A quantitative expression for volume in an electric circuit. The volume in vu is numerically equal to the number of decibels which expresses the ratio of the magnitude of the waves to the magnitude of reference volume The term vu should not be used to express results of measurements of complex waves made with devices having characteristics differing from those of the standard **volume indicator.**

VOLUME VELOCITY. The rate of flow of the medium through a specified area due to a sound wave. The terms "instantaneous volume velocity," "effective volume velocity," "maximum volume velocity," and "peak volume velocity" have meanings which correspond with those of the related terms used for **sound pressure.**

VOLUMETER METHOD FOR GAS DENSITY. The gas is contained in a large globe of known volume, and its pressure measured at a known temperature The gas is then transferred to a small bulb (e.g, by absorption on charcoal in the bulb at a low temperature), and the weight of gas found as the difference between two comparatively small quantities, thus avoiding the difficulty of weighing the large globe. An alternative method is to transfer the gas from the small bulb to the large bulb.

VON NEUMANN-WIGNER RULE. See **non-crossing rule.**

VON WEIMARN EQUATION. An expression for the rate of formation of particles of **colloidal** size from smaller particles such as ions and molecules. It has the form:

$$V_i = k\frac{P_1}{P_2},$$

in which V_i is the initial rate of "condensation" or coalescence, k is a constant, P_1 is the condensation pressure, and P_2 is the condensation resistance.

VORTEX LINE. (1) A line everywhere parallel to the local direction of the **vorticity.** In an incompressible, inviscid fluid, vortex lines are convected by the fluid. (2) A line of concentrated **vorticity** such as are found trailing from the free end of an **aerofoil.** Since vorticity is a solenoidal vector, the direction of the vorticity is parallel to the line.

VORTEX MOTION. The motion of a fluid with non-zero **vorticity.** We may distinguish: (1) Motion in which the vorticity is confined to small regions of space, i.e., **aerofoil** and **boundary layer theory,** motion of isolated vortices. (2) Motion in which the vorticity is everywhere nearly the same, i.e., small perturbations of a uniformly rotating fluid. (3) Viscous motion (4) Randomly distributed vorticity, i.e., turbulent motion.

VORTEX MOTION, LAWS OF. In an inviscid, incompressible fluid, **vorticity** is convected by the fluid and the **Kelvin circulation theorem** shows that the strength of vortex tubes remains constant. So fluid with vorticity remains distinct from fluid with no vorticity, however the flow develops. If the fluid is viscous, the Lagrangian rate of change of vorticity is given by

$$\frac{d\omega_i}{dt} = \omega_j\frac{\partial u_i}{\partial x_j} + \nu\frac{\partial^2\omega_i}{\partial x_j^2}$$

where ω_i, u_i are the components of vorticity and flow velocity parallel to $0x_i$, and ν is the kinematic viscosity. From this it follows that if a flow starts from rest, **vorticity** can only be produced by diffusion from the flow boundaries where vortex sheets are found.

VORTEX RING (OR COLLAR VORTEX). The motion associated with a closed circular vortex line of concentrated **vorticity.** Ring vortices form whenever fluid is given a local impulsive movement, e.g, smoke rings or ground explosions.

VORTEX, STATIONARY. A vortical motion steady in space and time. The standard example is the two stationary eddies found behind a cylinder placed in a stream of viscous fluid. Another is the bound vortex trailing from the wing-tip of an aircraft.

VORTICITY. The vector obtained by taking the **curl** of the flow velocity. It is also the

antisymmetric part of the velocity gradient tensor $\partial u_i/\partial x_j$ (u_i is the component of the velocity parallel to $0x_i$). It measures the rate of rotation of the fluid, e.g., in a uniformly rotating fluid the vorticity is twice the angular velocity.

VOWEL ARTICULATION. See **articulation, vowel.**

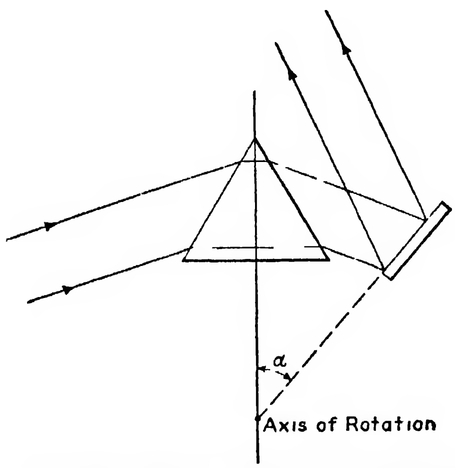
VTVM. Abbreviation for vacuum-tube voltmeter.

VU. See **volume unit.**

W

W. (1) Work (w or W). (2) Net work function, electronic (w), gross work function, electronic (w_g). (3) Water vapor content (w). (4) Watt (w). (5) Radiant flux density, or irradiance (W). (6) Tungsten (wolfram) (W). (7) Transverse acoustical displacement (w). (8) In spectroscopy, wide (w), very wide (W).

WADSWORTH MOUNTING. A device which operates as a constant-deviation prism. (See **prism. constant-deviation.**) The Wadsworth mounting is composed of a prism and



Spectrum Scanned by Changing Angle α

a plane mirror. This is a common mounting for infrared **spectrometers,** in which some infrared detector is placed outside of an exit slit. (See also **Littrow mounting,** in which the radiation, after reflection by the plane mirror, again passes through the prism.)

WAGNER GROUND. An addition to alternating current bridges (such as the **Wien bridge**) that is necessary to reduce errors when high impedances are involved. It consists essentially of two additional bridge arms which effectively balance the original bridge with respect to ground.

WAIDNER - BURGESS STANDARD. A standard of **luminous intensity** designed to supplant the Bureau of Standards **candle.** Defined as the luminous intensity of 1cm² of a **black body** at the melting point of platinum.

WAKE. The region behind a body moving through a fluid within which most of the effects of the body on the motion of the fluid are concentrated.

WALDEN RULE (WALDEN EMPIRICAL EQUATION). A relationship between the equivalent conductance at infinite dilution of a given electrolyte, Λ_0, and the viscosity of the solvent, η_0,

$$\Lambda_0\eta_0 = \text{constant}.$$

This rule has many limitations, and is most closely obeyed by ions of the type NR_4^+, where R is a relatively large radical.

WALL ENERGY. The **energy** (per unit area) of the boundary between oppositely oriented **ferromagnetic domains.**

WATER, CONDUCTIVITY. Water of exceptional purity, prepared by repeated distillation, and used in electrical conductivity measurements of aqueous solutions.

WATER, CONSTANTS OF. Temperature of maximum density, 4°C; viscosity (20°C), 1.008 centipoise; thermal conductivity, 6.30×10^{-3} watt cm^{-1} °C^{-1}; electrical conductivity, 0.04×10^{-6} ohm^{-1} cm^{-1}; dielectric constant, 81.1; ionization constant, 1.2×10^{-4}; hydrogen ion concentration, 1×10^{-7}.

WATER SPOUT. Funnel-shaped tornado cloud at sea or over water of lakes or rivers. It is the equivalent of a **tornado** but does not usually reach the same violence.

WATT. A unit of power, abbreviation W or w. The rate of energy consumption or conversion when one joule of energy is consumed or converted per second.

WATTHOURMETER. An **integrating meter** for measuring and/or recording the elec-

tric energy used during a period; in other words, the product of power and time.

WATTHOURMETER, COMMUTATOR-TYPE. Essentially an electrodynamic wattmeter (see **wattmeter, electrodynamic**) incorporating a commutator, so that it becomes a motor whose torque is proportional to load power By adding an eddy-current brake, its speed becomes proportional to power; hence a revolution counter indicates energy, usually in watthours.

WATTHOURMETER, INDUCTION. An a-c **watthourmeter** comprising a precision induction motor with magnetic braking.

WATTHOURMETER, MERCURY. A d-c motor type of meter (cf **watthourmeter, commutator-type**) in which commutator friction is almost eliminated by using a copper-disc rotor (Barlow wheel) connected via a mercury pool.

WATTHOURMETER, POLYPHASE. A pair of single-phase watthourmeter elements connected to a single shaft. (Cf. **wattmeter, polyphase.**)

WATTMETER(S). A meter for measuring power, which usually has two coils, one fixed, the other capable of turning in the field of the first, both coils being without iron cores The fixed coil is connected in series with the main circuit, so as to carry the whole current (or a known fraction of it, as determined by a shunt in d-c circuits or by a current transformer in a-c circuits). The movable coil, which is of high resistance, is connected across the terminals of the "load," that is, that portion of the circuit in which the power is to be measured, and the small current in the coil is therefore proportional to the voltage between these terminals. This coil turns against a hairspring, and since the torque is proportional to the product of the instantaneous values of the currents in the two coils, it is proportional to the product of the main current by the terminal voltage, that is, to the required power. The scale may therefore be graduated directly in **watts.**

WATTMETER, ASTATIC. An electrodynamic wattmeter (see **wattmeter, electrodynamic**) designed to be insensitive to uniform external magnetic fields.

WATTMETER, COMPENSATED. An electrodynamic wattmeter (see **wattmeter, electrodynamic**) with an added reversed "current coil" arranged to compensate for the current drawn by the voltage coil. This arrangement is needed when the load has a small power factor.

WATTMETER, COMPOSITE-COIL. An electrodynamic wattmeter (see **wattmeter, electrodynamic**) in which the torque produced by the alternating current being measured is balanced by an adjustable direct current applied to an auxiliary coil.

WATTMETER, ELECTRODYNAMIC. An **electrodynamometer** having its fixed coil (current coil) in series with the load, and its movable (voltage) coil connected across the load The resulting deflection is proportional to the average power.

WATTMETER, ELECTRONIC. A **wattmeter** comprising matched, **square-law** electronic **voltmeters.** One voltage is that appearing across the load, the other is obtained from an IR drop in the line By proper circuit arrangement, the combination can be made to yield the product of the two applied voltages, hence the power

WATTMETER, ELECTROSTATIC. A quadrant **electrometer** can be used as a **wattmeter.** A resistor carrying the load current provides a potential difference for the quadrant pairs. The load voltage is applied to the needle

WATTMETER, POLYPHASE. Three-phase power can be measured using two single-phase **wattmeters,** and adding readings. By using a single shaft for the two movements, the separate torques can be added mechanically, yielding a three-phase wattmeter.

WATTMETER, THERMOCOUPLE. A matched-pair, double-thermocouple **wattmeter,** one junction heated by the load voltage, the other by the load current

WATTMETER, TORSION-HEAD. An electrodynamic wattmeter (see **wattmeter, electrodynamic**) in which the deflection is reduced to zero by counter-rotation of the torsion head holding the torque spring. Such hand balancing of the torque makes the instrument slow in use, but considerably more precise than the deflection type of instrument.

WAVE. A disturbance which is propagated in a medium in such a manner that at any point in the medium the displacement is a function of the time, while at any instant the displacement at a point is a function of the position of the point. Any physical quantity which has the same relationship to some independent variable (usually time) that a propagated disturbance has, at a particular instant, with respect to space, may be called a wave. In this definition, displacement is used as a general term, indicating not only mechanical displacement, but also electric displacement, etc. In short, a wave is a time-varying quantity which is also a function of position; for example, any time-varying voltage or current in a **network** is often called a wave. Other examples of waves are: (1) wave on the surface of a liquid, in which the disturbance is the displacement of any particle in the surface from its equilibrium position; (2) acoustic wave, in which the disturbance is the change in pressure from its equilibrium value at any point in a material medium (fluid or solid); (3) electromagnetic wave, in which the disturbance is the change in the electric and magnitude field intensities from their equilibrium values in space. The first two types are known as mechanical waves, since the propagated disturbance involves motion of a medium.

WAVE ACOUSTICS. The analysis of acoustical problems under the assumption that sound travels in waves through a three-dimensional, bounded space.

WAVE AMPLITUDE. The magnitude of the maximum change from equilibrium of the disturbance characterizing the wave

WAVE ANTENNA (BEVERAGE ANTENNA). See **antenna, wave (beverage antenna).**

WAVE, BACKWARD. A **wave** propagating in a negative direction, as in the reflected wave in a mismatched transmission line.

WAVE CIRCUITS, SLOW. A microwave circuit designed to have a phase velocity considerably below the speed of light. The general application of such waves is in traveling-wave tubes. (See **traveling-wave tubes, circuits for.**)

WAVE, CIRCULAR-ELECTRIC. A transverse electric wave (see **wave, transverse electric**) for which the lines of electric force form concentric circles.

WAVE, CIRCULAR-MAGNETIC. A transverse magnetic wave (see **wave, transverse magnetic**) for which the lines of magnetic force form concentric circles.

WAVE, CIRCULARLY-POLARIZED. An electromagnetic wave for which the electric and/or the magnetic field vector at a point describes a circle. This term is usually applied to transverse waves. (See also **sound wave, circularly polarized.**)

WAVE, CIRCULATING. A **wave** of which the **equiphase surfaces** are half-planes issuing from an axis, called the axis of circulation. Such waves are possible only in non-dissipative media.

WAVE, COMPRESSIONAL. A **wave** in an elastic medium which causes an element of the medium to change its volume without undergoing rotation. (1) Mathematically, a wave whose **intensity field** has zero **curl.** (2) A compressional plane wave is a longitudinal wave (See **wave, longitudinal.**)

WAVE(S), CONTINUOUS OR CW. Waves, the successive oscillations of which are identical under **steady-state** conditions.

WAVE, CONVERGING. A spherical wave (see **wave, spherical**) which is traveling in the direction of decreasing radius.

WAVE CONVERTER. See **waveguide converter.**

WAVE CREST. The position of maximum positive disturbance in a progressive wave. (See **wave, progressive; wave trough.**)

WAVE CYCLONES. Cyclones which develop in the temperate zone are waves on frontal surfaces, in contrast with tropical cyclones in which fronts are not prominent features. Cyclones develop more frequently along a polar front than any other place, but they also appear on the inter-tropical front and on other minor fronts. It is on the polar front, however, that wave cyclones develop into major storms and climax their life as large-scale **vortices.**

WAVE, CYLINDRICAL. A **wave** whose **equiphase surfaces** form a family of coaxial or confocal cylinders.

WAVE(S), DAMPED. A term ordinarily used to designate electric waves which decrease in **amplitude** with time. In any oscillatory circuit which contains resistance (and all practical ones will) the oscillations will be dissipated in resistance losses, and the amplitude of the oscillations will gradually decrease unless energy is continually added to the circuit. When energy is added to overcome this dissipation and maintain the amplitude constant, continuous waves result. A **condenser** discharging through an **inductance** will give rise to damped waves, and this was the basis of the old spark radio transmitters where the spark gap initiated the discharge and the oscillations continued until all the energy had been dissipated. Since these waves are not as effective for radio transmission as the continuous waves, and since they give rise to interference by virtue of their broad frequency band, they are no longer used for this purpose.

WAVE, DECIMETRIC. See **decimetric waves.**

WAVE, DIFFRACTED. When a **wave** in a medium of certain propagation characteristics is incident upon a discontinuity or a second medium, the diffracted wave is the wave component that results in the first medium in addition to the incident wave and the waves corresponding to the reflected rays of geometrical optics.

WAVE, DIRECT. The **wave** which travels from the transmission source to the point of reception without reflection or refraction.

WAVE DISPLACEMENT. See **wave.**

WAVE DISTURBANCE. See **wave.**

WAVE, DIVERGING. A spherical wave (see **wave, spherical**) which is traveling in the direction of increasing radius.

WAVE, DOMINANT. The guided wave having the lowest **cut-off frequency.** It is the only wave which will carry energy when the **excitation frequency** is between the lowest cut-off frequency and the next higher cut-off frequency of a **waveguide.**

WAVE DUCT. \ **waveguide.**

WAVE, ELASTIC. A **wave** in which the disturbance is a change in some property of an elastic material medium (e.g., pressure, density). This is a mechanical wave.

WAVE, ELECTRIC. See **electric oscillations and electric waves.**

WAVE, ELECTROMAGNETIC. A wave characterized by variations of **electric** and **magnetic fields.** Electromagnetic waves are known as radio waves, heat waves, light waves, etc., depending on the frequency.

WAVE(S), ELECTROMAGNETIC PLANE, BASIC TYPES. The three basic types of electromagnetic plane wave are: (1) Transverse electromagnetic (TEM)—Both the **E** and **H** components of the field lie in the plane that is transverse to the direction of propagation. (2) Transverse electric (TE)—The **E** field lies wholly in the plane that is transverse to the direction of propagation, whereas the **H** field does not. (3) Transverse magnetic (TM)—The **H** field lies wholly in the plane that is transverse to the direction of propagation, whereas the **E** field does not.

WAVE, ELLIPTICALLY-POLARIZED. An electromagnetic wave (see **wave, electromagnetic**) for which the **electric** and/or the **magnetic field vector** at a point describes an ellipse. (See also **sound wave, elliptically polarized.**)

WAVE, ENERGY DENSITY. The total energy (kinetic plus potential in the case of a mechanical wave) per unit volume in the medium traversed by the wave. The average energy density multiplied by the wave velocity (for a harmonic progressive wave) is the intensity of the wave. (See **wave intensity.**)

WAVE EQUATION. The partial differential equation of wave motion. If ξ denotes the quantity characterizing the propagated disturbance, the equation in rectangular coordinates has the form

$$\frac{\partial^2\xi}{\partial x^2}+\frac{\partial^2\xi}{\partial y^2}+\frac{\partial^2\xi}{\partial z^2}=\frac{1}{V^2}\frac{\partial^2\xi}{\partial t^2}$$

where V is the velocity of the wave. Actually the above is the wave equation for waves that suffer no dissipative attenuation. More generally the wave equation is written in the form

$$\nabla^2\xi=\frac{1}{V^2}\frac{\partial^2\xi}{\partial t^2}$$

where ∇^2 is the **Laplacian operator,** which may be expressed in a variety of coordinate systems.

WAVE EQUATION, FORMS OF. (1) A form of the general wave equation, useful for solving problems in acoustics, is the following:

$$\frac{\partial^2\phi}{\partial t^2} - c^2\left(\frac{\partial^2\phi}{\partial x^2} + \frac{\partial^2\phi}{\partial y^2} + \frac{\partial^2\phi}{\partial z^2}\right) = 0$$

where ϕ is the velocity potential and c is the velocity of sound propagation.

(2) For problems in light, the general wave equation may be written as

$$\nabla^2 q = \frac{n^2}{c^2}\frac{\partial^2 q}{\partial t^2}$$

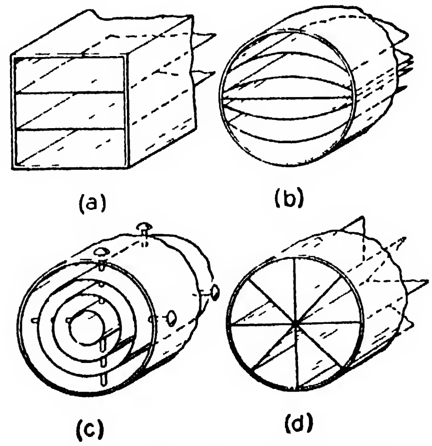
where n is the refractive index, c is the phase velocity and q is the displacement.

For a plane wave moving in the x-direction without attenuation:

$$q = a \sin 2\pi \left(\frac{t}{T} - \frac{x}{\lambda} - \delta\right)$$

where q is the displacement, a, the amplitude, T, the period, λ, the wavelength, t, the time variable, x, the space variable, and δ the epoch angle.

WAVE FILTER. (1) A **transducer** or **network** for separating waves on the basis of their frequency. It introduces relatively small insertion loss to waves in one or more frequency bands, and relatively large insertion loss to waves of other frequencies. (2) Another usage of the term wave filter, or wave type filter, is for a filter which acts primarily upon the mode rather than the frequency of the wave. The examples indicate four varieties and the modes they suppress.



Simple wave-type filters for rejecting unwanted components from various waves as follows: (a) TE_{01}; (b) TE_{11}; (c) TM_{01}; (d) TE_{01}. For notation see **wave, TE;** and **wave, TM.** (By permission from "Principles and Applications of Waveguide Transmissions" by Southworth, Copyright 1950, D. Van Nostrand Co., Inc.)

WAVE, FLEXURAL. A **wave** in an elastic medium which causes an element of the medium to change its volume and simultaneously to undergo rotation.

WAVEFORM. In a specific usage in communications, a current or voltage considered as a function of time in a rectangular coordinate system.

WAVEFORM-AMPLITUDE DISTORTION. Nonlinear distortion in the special case where the desired relationship is direct proportionality between input and output. Nonlinear distortion is also sometimes called **amplitude distortion.**

WAVE, FREE PROGRESSIVE (FREE WAVE). A wave in a medium free from **boundary effects.** A free wave in a steady state can only be approximated in practice.

WAVE FREQUENCY. In the case of harmonic waves the frequency is the number of **wave crests** which pass any given point in space in unit time. It is the reciprocal of the **period.**

WAVE FRONT. A surface at all of whose points the **phase** of the wave has the same value at a given instant. Wave propagation can be thought of as the motion of a wave front through a medium.

WAVE FRONT, PLANE. If the loci of points of constant phase of a beam of radiation are parallel planes, the wave fronts are called "plane" and the radiation is spoken of as "parallel."

WAVE FRONT, SPHERICAL. As radiation from a point source passes through a uniform medium, the loci of points with the same phase will be a series of concentric spheres. The radiation travels always normal to these spheres or wave fronts.

WAVE FUNCTION. The solution of a differential or partial differential equation for wave propagation through a medium.

WAVE FUNCTION, ADJOINT. See **adjoint wave function.**

WAVE FUNCTION OF A BOND. See **orbital.**

WAVE FUNCTION, SCHRÖDINGER. A function $x(\tau)$ of the coordinates that determines the state of a system and satisfies the **Schrödinger wave equation,** $Hx = ihdx/dt$, where H is the Hamiltonian operator and $i = \sqrt{-1}$. For a particle or a photon, the square of the wave function is proportional to the probability that the particle will be at a particular point at a particular time.

WAVE(S), GRAVITY. Surface waves whose motion is controlled by gravity and not by **surface tension.** In a liquid of depth h and density ρ, the wave-velocity of gravity waves of wavelength λ is

$$c = \left[\frac{g\lambda}{2\pi}\tanh\frac{2\pi h}{\lambda}\right]^{\frac{1}{2}}.$$

WAVE, GROUND. A **radio wave** that is propagated over the earth and is ordinarily affected by the presence of the ground and the **troposphere.** The ground wave includes all components of a radio wave over the earth except **ionospheric** and **tropospheric waves.** The ground wave is refracted because of variations in the dielectric constant of the troposphere, including the condition known as a **surface duct.**

WAVE, GROUND-REFLECTED. A wave reflected one or more times from the earth's surface before reaching the point of reception.

WAVE(S), GROUP VELOCITY OF. The velocity with which the envelope of a group of waves of neighboring frequencies travels in a medium in which the **phase velocity** is a function of frequency. It is

$$G = c - \lambda\frac{dc}{d\lambda},$$

and is usually identical with the velocity of energy propagation (c is wave velocity at wavelength λ).

WAVEGUIDE. A system of material boundaries capable of guiding **waves.**

WAVEGUIDE BRIDGE SECTION (HYBRID). See **magic tee; rat-race; microwave Wheatstone bridge.**

WAVEGUIDE CONNECTOR. A mechanical device for electrically joining separable parts of a **waveguide** system.

WAVEGUIDE CONVERTOR. See **transition element (1).**

WAVEGUIDE, DIELECTRIC. A **waveguide** consisting of a **dielectric** structure.

WAVEGUIDE FILTER. A **filter** composed of **waveguide** components.

WAVEGUIDE, FIN. A **waveguide** containing a thin, metallic longitudinal fin. The fin is generally applied to the circular waveguide as a means of increasing the wavelength range over which the waveguide may be operated.

WAVEGUIDE FREQUENCY FILTER. See **waveguide filter.**

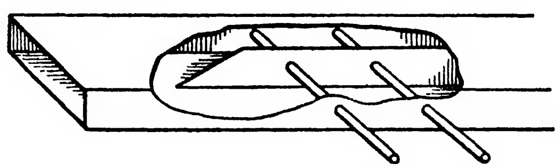
WAVEGUIDE HYBRID JUNCTION. See references under **waveguide bridge section (hybrid).**

WAVEGUIDE IRIS. See **iris.**

WAVEGUIDE, MATCHED. A **waveguide** having no reflected wave (see **wave, reflected**) at any transverse section.

WAVEGUIDE MODE SUPPRESSOR. A **filter,** of correct waveguide dimensions, which tends to suppress undesirable modes of propagation in the **waveguide.**

WAVEGUIDE PHASE SHIFTER. A device for adjusting the phase of a particular field component (or current or voltage) at output of device relative to the phase of that field component (or current or voltage) at the input. It may consist, in its simplest form, of merely a variable-length section so that the traveled path may be modified. Another method of obtaining a variable phase shift is to insert a slab of low-loss dielectric into the waveguide as shown in the figure. The



Dielectric phase shifter (By permission from "Microwave Theory and Techniques" by Reich et al., Copyright 1953, D. Van Nostrand Co., Inc.)

electrical length of the guide appears longer as the strip is moved towards the center, because of the decreased phase velocity which accompanies such a move.

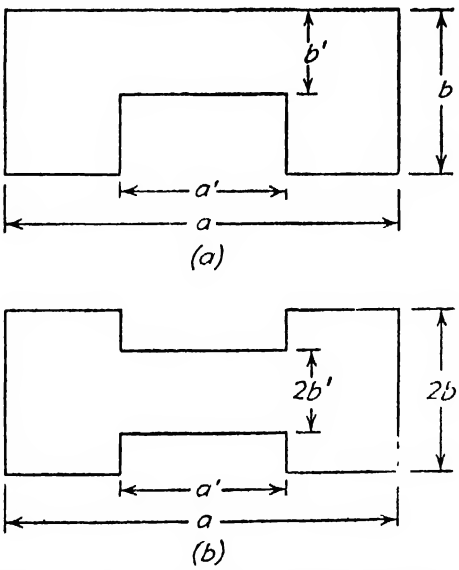
WAVEGUIDE PLUNGER. In a **waveguide,** a longitudinally-movable obstacle which reflects essentially all the incident energy.

WAVEGUIDE POST. In a **waveguide,** a cylindrical rod placed in a transverse plane of the waveguide and behaving substantially as a shunt **susceptance.**

WAVEGUIDE RADIATOR. An open-ended **waveguide.** For purposes of **matching** and **directivity,** the open-ended guide is customarily fitted with a **horn.**

WAVEGUIDE RESONATOR (RESONANT ELEMENT). A **waveguide** device primarily intended for storing oscillating electromagnetic energy.

WAVEGUIDE, RIDGE. A modification of a rectangular **waveguide,** which may have either a single or double ridge. The ridge or ridges act as a uniform, distributed-capacitance loading, and therefore reduce the characteristic impedance of the waveguide, and lower its phase velocity.



(a) Single ridge waveguide, (b) double-ridge waveguide (By permission from "Microwave Theory and Techniques" by Reich et al., Copyright 1953, D. Van Nostrand Co., Inc.)

WAVEGUIDE RING. See **rat-race.**

WAVEGUIDE SLUG TUNER(S). Quarter-wavelength long-dielectric slugs inserted into the waveguide for tuning purposes. In order that the widest variation of load conditions may be matched, two slugs, variable in position and depth of penetration, are usually employed.

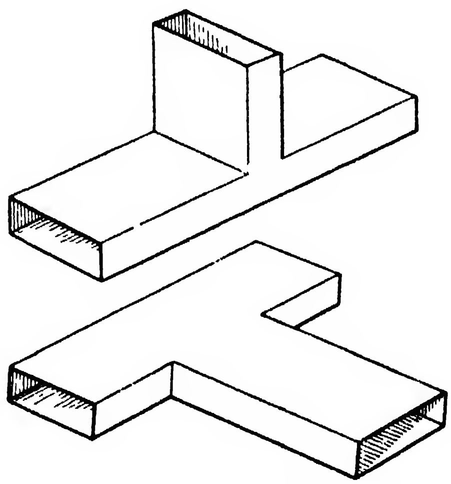
WAVEGUIDE, STUB. An auxiliary section of **waveguide** with an essentially nondissipative termination and joined at some angle with the main section of waveguide.

WAVEGUIDE STUB TUNER. A **waveguide** tuning (or detuning) device consisting of a piston in a short piece of pipe connected to the waveguide. Its dimensions and placement on the waveguide are such that changing the plunger position modifies the **susceptance** seen by the waveguide

WAVEGUIDE SWITCH. A waveguide component capable of switching waveguide power from one branch to another. As examples, see **resonant-chamber switch** and **resonant-iris switch.**

WAVEGUIDE, TAPERED. A **waveguide** in which a physical or electrical characteristic changes continuously with distance along the axis of the guide.

WAVEGUIDE TEE. A junction used for the purpose of connecting a branch section of **waveguide** in series or parallel with the main waveguide transmission-line.



Series tee (above); shunt tee (below) (By permission from "Microwave Theory and Techniques" by Reich et al., Copyright 1953, D Van Nostrand Co., Inc.)

WAVEGUIDE, TRANSFORMER. A device, usually fixed, added to a **waveguide** for the purpose of impedance transformation.

WAVEGUIDE TUNER. An adjustable device added to a **waveguide** for the purpose of impedance transformation.

WAVEGUIDE TWIST. A **waveguide** section in which there is a progressive rotation of the cross section about the longitudinal axis.

WAVEGUIDE, UNICONDUCTOR. A **waveguide** consisting of a metallic surface surrounding a uniform dielectric medium. Common cross-sectional shapes are rectangular and circular.

WAVEGUIDE, UNIFORM. A **waveguide** in which the physical and electrical characteristics do not change with distance along the axis of the guide.

WAVEGUIDE WAVELENGTH. For a **traveling plane-wave** at a given frequency, the distance along the **waveguide** between points at which a field component (or the voltage or current) differs in phase by 2π radians.

WAVE, GUIDED. A **wave** whose energy is concentrated near a boundary, or between substantially parallel boundaries, separating materials of different properties, and whose direction of **propagation** is effectively parallel to these boundaries.

WAVE, HARMONIC. A **wave** in which the disturbance at any point in space through which the wave is propagated varies sinusoidally with the time. Specifically if the wave is a plane harmonic wave in the x-direction, the disturbance ξ is given by

$$\xi = A \sin (\omega t - kx)$$

where A is the wave amplitude, $\omega = 2\pi f$ (where f is the frequency) and $k = \omega/V$ (where V is the wave velocity). (Cf. **wave propagation.**)

WAVE, HORIZONTALLY POLARIZED. A linearly **polarized wave** whose **electric field vector** is horizontal.

WAVE, HYBRID ELECTROMAGNETIC (HEM WAVE). An electromagnetic wave having components of both the **electric** and **magnetic field vectors** in the **direction of propagation.**

WAVE IMPEDANCE. The ratios of appropriate components of **electric field strength, E,** to those of **magnetic field strength, H,** are often called wave impedances, by a useful generalization of a **network** concept.

WAVE(S) IN A ROD, TORSIONAL, VELOCITY OF PROPAGATION OF. For a homogeneous bar of circular cross-section, the velocity of propagation, c, in cm/sec is given by

$$c = \sqrt{\frac{Y}{2\rho(\sigma + 1)}}$$

where Y is the Young modulus in dynes/cm^2, ρ is the density in gm/cm^3, σ is the Poisson ratio.

WAVE, INCIDENT. In a medium of certain propagation characteristics, a wave which impinges on a discontinuity or a medium of different propagation characteristics.

WAVE INTENSITY. The average rate of flow of energy in the direction of propagation per unit area of the **wave front.** (Cf. **wave energy density.**)

WAVE INTERFERENCE. The variation of wave amplitude with distance or time, caused by the superposition of two or more waves. As most commonly used, the term refers to the interference of waves of the same or nearly the same frequency. Wave interference is characterized by the phenomenon of the occurrence of local maxima and minima of wave amplitude which cannot be described by the ray approximation to solutions of the wave equation. In terms of **Huygens approximation,** interference can occur whenever wave disturbance can be propagated from a source to a region of space by two or more paths of different length. There is (destructive) interference if the phases and amplitudes of the disturbances arriving by the various routes are such as to reduce the square of the resultant amplitude below the sum of the squares of the amplitudes of the components. Two or more sources may only be used if there is a fixed phase relation between them, i.e., if they are sources of **coherent radiation.**

WAVE, IRROTATIONAL. An elastic wave in which the **curl** of the **vector displacement** from equilibrium vanishes. A **plane irrota-**

tional wave is longitudinal. (See **wave, longitudinal.**)

WAVE, KINETIC ENERGY DENSITY. The kinetic energy per unit volume in a medium traversed by a mechanical wave. It is a function of time and space.

WAVE, LEFT-HANDED (COUNTER-CLOCKWISE) POLARIZED. An elliptically-polarized, transverse **electromagnetic wave** in which the rotation of the **electric field vector** is counter-clockwise for an observer looking in the direction of **propagation.**

WAVELENGTH. Of a periodic wave in an **isotropic medium,** the perpendicular distance between two **equiphase surfaces** in which the displacements have a difference in phase of one complete period. Otherwise phrased, the wavelength is the "space period" of a wave, i.e., the least translation distance that leaves the wave invariant.

In a harmonic wave the wavelength is the distance between any two points at which the phase at the same instant differs by 2π, specifically if the wave is a plane harmonic wave in the x-direction with angular frequency ω, so that the disturbance has the form

$$\sin(\omega t - kx)$$

the wavelength is

$$\lambda = 2\pi/k = 2\pi V/\omega$$

where V is the **wave velocity.**

WAVELENGTH ASSOCIATED WITH ONE ELECTRON-VOLT. By combining the basic relation of **quantum theory** that the energy of a photon is the **Planck constant** multiplied by the frequency, with the energy which an electron receives in falling through one volt of potential difference, there results a wavelength associated with one electron-volt of $12{,}395 \times 10^{-8}$ cm (Birge, 1941).

WAVELENGTH, COMPLEMENTARY. (1) The wavelength of **light** of a single frequency (practically, a narrow band of frequencies), which matches the reference standard light (usually white light) when combined with a sample color in suitable proportions. The wide variety of purples which have no dominant wavelengths (see **wavelength, dominant**) including nonspectral violet, purple, magenta, and nonspectral red colors, are specified by use of their complementary wavelengths. (2) A wavelength represented by a point on the **chromaticity diagram,** which lies at the intersection of the **spectrum locus** with the straight line connecting the **sample point** and the **achromatic point.** The intersection on the same side of the achromatic point as the sample is the dominant wavelength, that on the opposite side is the complementary wavelength.

WAVELENGTH CONSTANT. The **wave equation:**

$$q = a \sin 2\pi \left(\frac{t}{T} - \frac{x}{\lambda} + \delta\right)$$

is sometimes written as

$$q = a \sin \left(\frac{2\pi}{T} t - \frac{2\pi}{\lambda} x + \epsilon\right).$$

$\frac{2\pi}{T} = \omega$, the "angular velocity" or "angular frequency." $\frac{2\pi}{\lambda} = \kappa$ is called the wavelength constant or, sometimes, the **wave number** or **wave parameter.**

WAVELENGTH, CROVA. See **Crova wavelength.**

WAVELENGTH, CUT-OFF (OF A UNI-CONDUCTOR WAVEGUIDE). See **cut-off wavelength.**

WAVELENGTH, DOMINANT. That wavelength of spectrally-pure light which, when mixed with white light, matches the **chromaticity** of a given sample.

WAVE, LINEARLY POLARIZED. At a point in a homogeneous, isotropic medium, a transverse electromagnetic wave whose **electric field vector** at all times lies along a fixed line.

WAVE, LONGITUDINAL. A wave in which the direction of displacement at each point of the medium is normal to the **wave front.**

WAVE, MATTER. See **de Broglie wavelength; Schrödinger wave equation; wave mechanics.**

WAVE MECHANICS. Wave mechanics is a more or less direct outgrowth of the **quantum theory,** and an integral part of **quantum**

mechanics. The fact that radiant **energy** (light, x-rays, etc.) is certainly emitted by atoms or molecules and is as certainly done up in parcels, called quanta, the magnitude of each of which is definitely associated with a vibration or wave frequency of some kind, leads one to inquire what there is about an atom or the electrons in it that has to do with vibrations or waves. The now classic **Davisson-Germer experiment** gave most conclusive evidence that electrons actually do have wave characteristics even when flying freely through space (or at least when they strike and rebound from something like a crystal), and that, again, the energy of their motion is expressible in terms of a wave or vibration frequency. Even whole atoms are reflected by crystals as if they were waves, as shown by the experiments of Ellett, Olson, and Zahl

Such facts have given rise to the idea that perhaps all physical processes are, in the last analysis, wave processes, with frequencies or wavelengths appropriate to the quanta into which the energy divides itself Instead of being particles which revolve in orbits like planets, the electrons in the atom, according to this conception, become wave trains reverberating like sound in a closed room, and setting up stationary **interference** patterns corresponding to the stationary quantum states. It is of such boldly revolutionary concepts that the new wave mechanics is built. The mathematical formulation of the theory has been developed largely by de Broglie and by Schrödinger.

WAVEMETER. A device for determining the wavelength (frequency) of an electric wave (See **wavemeter, absorption,** as one example.)

WAVEMETER, ABSORPTION. A device which utilizes the characteristics of a **resonator** which cause it to absorb maximum energy at its **resonance frequency** when loosely coupled to a source The absorption wavemeter consists of some form of calibrated resonator, a device for detecting resonator energy (voltage, current), and some means of lightly-coupling the wavemeter to the unknown source. The measurement process consists of providing coupling, adjustment of resonator for maximum energy-indication, and observation of the point at which the calibrated resonator is set, which will be the unknown frequency.

WAVE MOTION. See **wave.**

WAVE NORMAL. The curves of a family normal to the **equiphase surface** of a wave are called wave normals. The equiphase surfaces are those satisfying $\Phi(x,y,z) =$ constant for the wave $A(x,y,z)e^{j[\omega t - \Phi(x,y,z)]}$. Wave normal may also be defined as a unit vector normal to an equiphase surface, with its positive direction taken on the same side of the surface as the direction of propagation. In isotropic media, the wave normal is in the direction of propagation.

WAVE NUMBER. The reciprocal of the **wavelength** in a harmonic wave. Some authors use $2\pi/\lambda$ instead of $1/\lambda$ in this sense. (See **wave parameter** and **wave constant.**)

WAVE PARAMETER. The quantity $2\pi/\lambda$, commonly symbolized by k (See also **wave number** and **wave constant.**)

WAVE PATH, TANGENTIAL. In **radio wave propagation** over the earth, a path of propagation of a direct wave, which is tangential to the surface of the earth The tangential wave path is curved by atmospheric refraction.

WAVE PERIOD. In a harmonic wave the time between attainment of successive maximum disturbances at the same place. The reciprocal of the **frequency.**

WAVE, PERIODIC. A wave in which the disturbance repeats itself in equal intervals of time at each point of space and at equal intervals of space at each given instant of time.

WAVE, PERIODIC ELECTROMAGNETIC. A wave in which the **electric field vector** is repeated in detail in either of two ways: (1) At a fixed point, after the lapse of a time known as the period, (2) at a fixed time, after the addition of a distance known as the wavelength.

WAVE PHASE. The argument in the **wave function.** Thus in the general arbitrary progressive wave function $f(x - Vt)$ the phase is $x - Vt$. For a harmonic plane wave in which the disturbance has the form sin $(\omega t - kx)$, the phase is $\omega t - kx$. Here ω is the angular frequency $= 2\pi f$, where f is the actual frequency, $k = 2\pi/\lambda$, where λ is the wavelength.

WAVE(S), PHASE VELOCITY OF. The velocity with which a point of constant phase is propagated in a progressive sinusoidal wave.

WAVE, PLANE. A three-dimensional wave depending only upon time and one rectangular, spatial coordinate. The **equiphase surfaces** are planes. In other words, a plane wave is a wave whose equiphase surfaces form a family of parallel planes.

WAVE, PLANE-POLARIZED. At a point in a homogeneous isotropic medium, an **electromagnetic** wave whose **electric field vector** at all times lies in a fixed plane which contains the direction of **propagation.** (See also **sound wave, plane-polarized.**)

WAVE, POTENTIAL ENERGY ASSOCIATED WITH. Any unit volume of an elastic medium traversed by a wave will possess at a given instant a certain total energy, called the energy density. This will be made up of two parts: (1) the kinetic energy density, which is simply one-half the product of the mass density and the square of the instantaneous particle velocity and (2) the potential energy density which is the energy per unit volume due to the elastic distortion of the medium (e.g., compression or rarefaction). The general form of the potential energy density is one-half the product of an appropriate elastic modulus and the square of the instantaneous strain associated with the wave disturbance.

The product of the time average of the total energy density and the velocity of propagation is the intensity of the wave. (See **wave-intensity.**)

Strictly speaking, the concept of potential energy density of a wave applies only to elastic waves, where actual motion of a material medium is involved.

WAVE POTENTIALS. A sinusoidal, **electromagnetic wave** of angular frequency ω can be expressed as derived from four wave potentials:

(1) The magnetic vector potential, **A**.
(2) The electric vector potential **F**.
(3) The electric scalar potential

$$V = -\frac{\nabla \cdot \mathbf{A}}{\sigma + j\omega\epsilon}.$$

(4) The magnetic scalar potential

$$U = -\frac{\nabla \cdot \mathbf{F}}{j\omega\mu}.$$

The field is given by

$$\mathbf{E} = -j\omega\mu\mathbf{A} - \nabla V - \nabla \times \mathbf{F}$$

$$\mathbf{H} = \nabla \times \mathbf{A} - \nabla U - (\sigma + j\omega\epsilon)\mathbf{F}.$$

WAVES, PROGRESSIVE. Traveling waves, as opposed to stationary waves. (See **wave, standing.**)

WAVE PROJECTOR. An **antenna.**

WAVE, REFLECTED. When a wave in a medium of certain propagation characteristics is incident upon a discontinuity or a second medium, the wave component that results in the first medium in addition to the incident wave. (See **wave, incident.**)

WAVE, REFRACTED. That part of an incident wave (see **wave, incident**) which travels from one medium into a second medium.

WAVE(S), REINFORCEMENT OF. Interference of waves (see **wave(s), interference**) when the square of the resultant amplitude exceeds the sum of the squares of the amplitudes of the components.

WAVE, RIGHT-HANDED (CLOCKWISE) POLARIZED. An elliptically-polarized, transverse electromagnetic wave in which the rotation of the **electric field vector** is clockwise for an observer looking in the direction of **propagation.**

WAVE, SAWTOOTH. A periodic **wave** whose amplitude varies, substantially linearly with time, between two values, the interval required for one direction of progress being longer than that for the other.

WAVE SHEAR (ROTATION WAVE). A **wave** in an elastic medium which causes an element of the medium to change its shape without a change of volume. Mathematically, a wave whose **velocity field** has **zero divergence.** A shear plane wave in an isotropic medium is a transverse wave. (See **wave, transverse.**)

WAVE, SIMPLE HARMONIC. A **wave** in which the disturbance at any place is a simple harmonic function of the time. Specifically for a simple harmonic wave of angular

frequency ω traveling with velocity V the disturbance ξ has the form

$$\xi = A \sin \omega \left(t - \frac{x}{V}\right).$$

(See **wavelength.**)

WAVE, SOLENOIDAL. A **wave** in which the divergence of the vector quantity representing the disturbance vanishes identically. A plane solenoidal elastic wave is a transverse wave. (See **wave, transverse.**)

WAVE, SPACE. A **wave** reaching the reception point which is made up of **ground-reflected** and **direct waves.**

WAVE, SPHERICAL. A **wave** whose **equiphase surfaces** form a family of concentric spheres.

WAVE(S), SPHERICAL, INCIDENT ON A THIN LENS.

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = (n - 1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right).$$

Here p and q are the radii of curvature of the incident and refracted light, r_1 and r_2 are the radii of curvature of the first and second surfaces of the lens and n is the **index of refraction** of the material of the lens with respect to the medium in which it is immersed.

WAVE(S), SPHERICAL, REFLECTION AT A PLANE SURFACE. Spherical waves after reflection at a plane surface are again spherical waves about a new center, as far behind the reflecting surface as the source (real or virtual) of the original spherical waves was in front of the surface

WAVE(S), SPHERICAL, REFRACTION AT PLANE SURFACE. Spherical waves refracted at a plane boundary between two transparent media are again spherical waves, but with the larger radius of curvature in the more dense medium (See Robertson, *Introduction to Optics*, 4th Ed., page 31 ff.)

WAVE, STANDING. A wave disturbance which is not progressive, i e., one in which any component of the field can be specified as a function of position multiplied by a sinusoidal function of time. Standing waves result from the superposition of two waves traveling in opposite directions, having identical amplitudes and frequencies. Thus, if two plane waves, both having amplitudes A, wavelength λ, and frequency f, are traveling in opposite directions along the x-axis, their combined effect at the position x and at time t is

$$y = A \sin 2\pi\left(\frac{x}{\lambda} - ft\right) + A \sin 2\pi\left(\frac{x}{\lambda} + ft\right)$$

$$= 2A \sin \frac{2\pi x}{\lambda} \cos 2\pi ft$$

The points $x = n\lambda/2$ (n an integer), at which $\sin 2\pi x/\lambda = 0$, show no disturbance and are known as **nodes (1).** The disturbance is maximal at $x = (2n + 1)\lambda/4$, and such points are called **antinodes** or **loops.**

WAVE, STANDING, RATIO. See **wave, standing, voltage ratio.**

WAVE, STANDING, VOLTAGE RATIO. The ratio of the maximum to the minimum voltage of the standing wave. (See **wave, standing.**)

WAVE, STATIONARY. See **wave, standing.**

WAVE(S), SURFACE. (1) Waves of distortion on the free surface separating two fluid phases, usually a liquid and a gas or vapor of low density The waves are classed as gravitational waves or ripples, depending on whether gravity or surface tension is the controlling force in their motion. (2) An electromagnetic wave component traveling parallel to the earth's surface. (Also called the **ground wave.**)

WAVE, $TE_{m,n}$ (IN CIRCULAR WAVEGUIDE). In a hollow circular metal cylinder, the transverse electric wave for which m is the number of axial planes along which the normal component of the electric vector vanishes, and n is the number of coaxial cylinders (including the boundary of the waveguide) along which the tangential component of electric vector vanishes $TE_{0,n}$ waves are circular electric waves of order n. The $TE_{0,1}$ wave is the circular electric wave with the lowest cut-off frequency. The $TE_{1,1}$ wave is the dominant wave. Its lines of electric force are approximately parallel to a diameter.

WAVE, $TE_{m,n}$ (IN RECTANGULAR WAVEGUIDE). In a hollow rectangular metal cylinder, the transverse electric wave for which m is the number of half-period variations of the electric field along the longer transverse dimension, and n is the number of half-period

variations of the electric field along the shorter transverse dimension.

WAVE, TIDAL. (1) A gravitational wave in the sea or the atmosphere induced by gravitational or thermal effects of the moon or sun. (2) A gravitational wave in which the vertical movement of fluid particles is negligible compared with the horizontal movement. For water waves, this requires that the wavelength should be large compared with the depth of water, h, and the **wave** (and **group**) **velocity** is

$$c = \sqrt{gh}.$$

WAVE, TM$_{m,n}$ (IN CIRCULAR WAVEGUIDE). In a hollow circular metal cylinder, the transverse magnetic wave for which m is the number of axial planes along which the normal component of the magnetic vector vanishes, and n is the number of coaxial cylinders to which the electric vector is normal TM$_{0,n}$ waves are circular magnetic waves of order n. The TM$_{0,1}$ wave is the circular magnetic wave with the lowest **cut-off frequency.**

WAVE, TM$_{m,n}$ (IN RECTANGULAR WAVEGUIDE). In a hollow rectangular metal cylinder, the transverse magnetic wave for which m is the number of half-period variations of the magnetic field along the longer transverse dimension, and n is the number of half-period variations of magnetic field along the shorter transverse dimension.

WAVE TRAIN. The series of waves produced by a "vibrating" body is called a train of waves.

WAVE-TRAIN SHAPE. Waves in general are not simple single frequency and phase, sine (or cosine) waves, but are combinations of a number of overtones superimposed on a fundamental. Hence a plot of the **amplitude** vs. distance along the wave may have almost any shape, but is properly single-valued and continuous, with continuous derivatives.

WAVE, TRANSMITTED. When a **wave** in a medium of certain propagation characteristics is incident upon a discontinuity or a second medium. the forward traveling wave that results in the second medium. In a single medium the transmitted wave is that wave which is traveling in the forward direction.

WAVE, TRANSVERSE. A **wave** in which the direction of displacement at each point of the medium is parallel to the **equiphase surface.**

WAVE, TRANSVERSE ELECTRIC (TE WAVE). In a homogeneous isotropic medium, an **electromagnetic wave** in which the **electric field vector** is everywhere perpendicular to the **direction of propagation.**

WAVE, TRANSVERSE ELECTROMAGNETIC (TEM WAVE). In a homogeneous isotropic medium, an **electromagnetic** wave in which both the **electric** and **magnetic field vectors** are everywhere perpendicular to the **direction of propagation.**

WAVE, TRANSVERSE MAGNETIC (TM WAVE). In a homogeneous isotropic medium, an **electromagnetic wave** in which the **magnetic field vector** is everywhere perpendicular to the **direction of propagation.**

WAVE TRAP. See **trap.**

WAVE, TRAVELING PLANE. A plane wave each of whose frequency components has an exponential variation of amplitude and a linear variation of phase in the **direction of propagation.**

WAVE TROUGH. A point of minimum (algebraic) value of the disturbance in a progressive wave. Opposite of **wave crest.**

WAVE, UNIFORM CYLINDRICAL. A wave whose **equiphase surfaces** form a family of coaxial cylinders, with the wave **amplitude** the same at all points of a given **equiphase surface.**

WAVE, UNIFORM PLANE. A plane wave in which the **electric** and **magnetic field vectors** have constant amplitude over the **equiphase surfaces.** Such a wave can only be found in free space at an infinite distance from the source.

WAVE VELOCITY OR PHASE VELOCITY. A plane wave has a velocity uniquely defined as the reciprocal of the **phase slowness.** The wave velocity is thus the velocity with which the **displacement profile** of a sinusoidal progressive wave travels In three dimensions, the reciprocal of the magnitude of the (vector) phase slowness is the speed of the wave along a **wave normal,** and is often called phase velocity.

WAVE-VELOCITY SURFACE. An elliptical surface used to indicate the difference in the velocity of the ordinary and the extraordinary ray of radiation in different directions in a double-refracting crystal. (See **double refraction.**)

WAVE, VERTICALLY-POLARIZED. A linearly-polarized wave whose **magnetic field vector** is horizontal.

WEAK COUPLING. See **coupling, weak.**

WEAK ELECTROLYTE. See **electrolyte, weak.**

WEAK EQUALITY. Equality between two **operators** which does not imply that the **Poisson bracket** with any operator of the difference between them is zero.

WEATHER. All the atmospheric phenomena occurring for short periods such as hourly or daily. Thus, existing phenomena constitute weather, while the average weather over long periods of time constitutes climate.

WEATHER ANALYSIS. **Synoptic** weather reports received from a relatively large area, i.e., part of a continent, or part of the world, are plotted on a weather chart in a systematic manner The chart is then analyzed in such a manner that **fronts, isobars, isallobars, isotherms,** precipitation areas, clouded areas, and **air masses** are indicated Also, forecast movements of prominent features are usually indicated.

WEATHER PHENOMENA, OROGRAPHICAL. See **orographical weather phenomena.**

WEATHERING OF GLASS. The surface chemical attack and change in glass due to exposure to the atmosphere. Weathered glass is apt to give much more trouble due to gassing when used in vacuum apparatus than is fresh glass.

WEBER. The mksa unit of **magnetic flux.** It is that flux which, when linked with a single turn, generates an electromotive force of one volt in the turn, as it decreases uniformly to zero in one second

WEBER DIFFERENTIAL EQUATION. The second-order equation

$$y' + (n + \tfrac{1}{2} - \tfrac{1}{4}x^2)y = 0.$$

It has an **irregular singular point** at ∞ and occurs in solving the wave equation in **parabolic cylindrical coordinates.** It is a special case of the **confluent hypergeometric equation** and its solutions are **confluent hypergeometric series.**

WEBER LAW. A psychophysical relationship which states that the minimum perceptible difference between the physical magnitudes of stimuli is a constant fraction of one of them.

WEDDLE RULE. A procedure for **numerical integration.** If $y_0, y_1, y_2, \cdots, y_6$ are the values of $y = f(x)$ at seven equally-spaced values of $x_0, x_1, \cdots, x_6$ and $h = x_i - x_j$, then

$$\int_{x}^{x_6} f(x)dx = \frac{3h}{10}(y_0 + 5y_1 + y_2 + 6y_3 + y_4 + 5y_5 + y_6) + R$$

where R is a remainder term, giving the error in the value of the integral

WEDGE. (1) A simple machine in the form of a triangular prism The theoretical **mechanical advantage** is the ratio of the length to the base (2) In television, those portions of a **test pattern** containing a series of lines which converge at one end, this end generally positioned at the center of the pattern.

WEDGE LINE. A line drawn symmetrically in a wedge of pressure along which the **isobars** are curved anticyclonically and symmetrically. Wedge lines or wedges or pressure are elongated **anticyclones** and are always U-shaped, in contrast to trough lines which often are V-shaped.

WEDGE PHOTOMETER. In the many forms of **bench photometer,** the illuminations or luminous flux densities from the two sources to be compared are made equal by regulating the relative distances. In photometers of the wedge type, the same object is accomplished by pushing into the beam from the brighter source a graduated wedge of absorbing material until its intensity is cut down to equality with that from the other source The scale reading on the wedge indicates the ratio in which the flux density has been reduced, and hence the **luminous intensity** ratio of the two sources. It is highly important that the absorbing wedge shall be "neutral," that is, not selective as to wavelength, in its absorption;

otherwise there will be an alteration of color as well as of total intensity.

WEIERSTRASS ELLIPTIC FUNCTION. The elliptic integral

$$u = \int_x^\infty \frac{dt}{\sqrt{4t^3 - g_2 t - g_3}}$$

defines x as a function of u, where g_2 and g_3 are **parameters.** The quantity $x = \wp(u)$ is the **Weierstrass elliptic function.** It is doubly **periodic,** has double **poles,** and satisfies the **differential equation**

$$\left(\frac{d\phi}{dx}\right)^2 = 4\phi^3 - g_2\phi - g_3.$$

WEIGHING METHODS. The use of a **balance** for measuring masses is something more than the mere placing of equal weights on the two pans. The chief reasons are that the refinement required often goes beyond the smallest weights in any set, and that the arms of a balance are never exactly equal in length.

The former condition is commonly met by the use of a "rider," a small weight (usually 1 milligram) sliding along a scale on the beam. The most approved procedure, however, makes use of the known sensibility of the balance, expressed in divisions of the pointer scale per unit excess weight on one pan. The arm inequality may be allowed for by the substitution method, in which the object to be weighed is first counterpoised, or nearly so, and then replaced by known weights on the same pan, the small difference in pointer reading being noted and the difference in weight computed from it.

Both difficulties can be met at once by the method of "double weighing." The object is first placed on the left pan and weights nearly equal to it on the right, the resulting pointer reading being r_1. The object and weights are now interchanged, with pointer reading r_2. Then if the sensibility of the balance is s, and if the weights used total a value w, the weight of the object is given by

$$W = w + \frac{r_1 - r_2}{2s}.$$

The sensibility is, in general, a function of the load, and before precise weighing is attempted, a table or a graph should be prepared from which s can be obtained from the value of w. When the pointer is used, it should not be allowed to come to rest, but its equilibrium position should be deduced from the extremes of its small oscillation (see **damping**).

It is of course presumed in any case that the errors of the weights themselves have been accurately determined. Due allowance must also be made in precise weighing, for the buoyancy of the air, or rather for the difference of the buoyant force on the object to be weighed and that on the weights in the opposite pan. If the weights are mainly of brass (density 8.4 g/cm³), the corrected or "vacuum" weight of an object of volume V (cm³), weighed in air of density ρ (g/cm³), is

$$W_0 = \left(1 - \frac{\rho}{8.4}\right) W + V\rho,$$

where W is the uncorrected result of the weighing. Under ordinary laboratory conditions, the value of ρ is approximately 0.00119 g/cm³, giving 0.99986 as the coefficient of W in the above formula.

WEIGHT. The force with which a body is attracted toward the earth; the product of the mass of a body and the acceleration attributable to gravity. The force of 980 dynes is the weight of one gram at the place where the acceleration of gravity equals 980 cm/sec². The value of the acceleration due to gravity increases slightly from equator to pole so that the weight of a body varies according to its geographical location. The mass of a body, however, is constant.

In view of the difficulty, under most circumstances, of determining mass directly, masses are commonly determined in chemical operations by comparison of the weight of the unknown mass with the weight of known masses, a process called weighing, which involves, in very accurate work, certain corrections or methods to avoid the necessity for those corrections. (See **weighing methods.**)

Although the above definition is satisfactory in most cases, some ambiguities in the meaning of the term "weight" may arise, and various authors differ in its use. For example, the weight of a solid object submerged in a fluid less dense than itself may be said to be either the same as that of the body in air or equal to the weight in air less the **buoyancy.** Some writers speak of the latter as the apparent weight. An even finer dis-

tinction arises when we ask whether the weight of an object is the gravitational force on it, or whether it is that force added vectorially to the **centrifugal force** resulting from the earth's rotation. Because of the wide variety of usage, one must often judge from context as to the exact meaning of the term in doubtful instances.

WEIGHT, COMBINING. (EQUIVALENT, REACTING, OR SYMBOL WEIGHTS.) The number of parts by weight of any element which can enter into combination with one part, by weight, of hydrogen or eight parts, by weight, of oxygen, or the atomic weight divided by the **valence.** Where an element possesses more than one valence the equivalent weight will depend upon the sense in which the element is reacting. In ferrous salts the equivalent weight of iron is 27.925 (55.85 ÷ 2) and in ferric salts it is 18.613 (55.85 ÷ 3). The equivalent weight of a compound is its molecular weight divided by the valence of its principal element.

WEIGHT, MOLECULAR. The weight of a molecule of any substance referred to a standard. By international agreement the base for this standard is the **atomic weight** of natural oxygen taken as 16. (However, in the so-called "physical" atomic weight the basis is the oxygen isotope of mass number 16, and not natural oxygen, which consists of isotopes of mass numbers 16, 17, and 18.) Chemical molecular weights are therefore less than physical molecular weights by a factor

$$\frac{16.0000}{16.0044} = \frac{1.00000}{1.00028}.$$

WEIGHTING. (1) The artificial adjustment of measurements in order to account for factors which, in the normal use of the device, would otherwise be different from the conditions during measurement. For example, background noise measurements may be weighted by applying factors or by introducing networks to reduce measured values in inverse ratio to their interfering effects. (2) When several different determinations of the same physical quantity have been made, the more accurate of the measurements should be counted more heavily than the less accurate in estimating the most probable value of the quantity. Thus, if q_1, q_2, etc., are the individual values, the most probable value is

$$q = \frac{w_1q_1 + w_2q_2 + \cdots}{w_1 + w_2 + \cdots},$$

where w_1, w_2, etc., are weighting factors. The theory of the propagation of errors shows that the weighting factor for any individual determination is inversely proportional to the square of the **uncertainty** of that determination. The quantity q is called the weighted mean. (3) In **statistical mechanics,** certain states of a system are often more probable than others, especially when **degeneracy** is present. In computing average values, these states must be weighted with factors proportional to their probabilities, the computation then proceeding as in (2) above.

WEIR. Any **dam** or **bulkhead** over which water flows, or a bulkhead containing a notch through which water flows, the notch at no time becoming completely submerged. A weir is usually employed to measure the volume in a flow of water. This it accomplishes through the fact that a discharge through a weir bears a certain definite relationship to the **head** of water over its crest, and this head is comparatively easy to measure.

WEISS THEORY OF FERROMAGNETISM. A theory of **ferromagnetism** based on an ensemble of independent molecular magnets, each of moment μ_1, subject to the aligning effect of **magnetizing force,** and the disorienting effect of thermal agitation. The average component of atomic moment in the direction of the field turns out to be

$$\overline{\mu_A} = \mu_1 \left\{ \operatorname{ctnh} \frac{\mu_A H}{kT} - \frac{kT}{\mu_1 H} \right\}$$

where H is the applied field; k, the **Boltzmann constant;** and T, the absolute temperature.

WEISSENBERG METHOD. An experimental technique for the **x-ray analysis** of **crystal structure** in which, whilst the crystal is rotated in the beam of x-rays, the photographic plate is moved parallel to the axis of rotation, the crystal being surrounded by a sleeve having a slot which is set so as to pass only one **layer line.** In this way, the various spots on the pattern may be positively identified.

WEIZSÄCKER - WILLIAMS METHOD. Method of computing **bremsstrahlung** emitted

in the collision of two particles with relative kinetic energy large compared with their rest energy. In the system in which one particle is at rest the field of the other is equivalent to a set of virtual light waves which are **Compton scattered** by the particle at rest.

WENNER DIFFERENCE POTENTIOMETER. See **potentiometer, Wenner-difference.**

WENTZEL-KRAMERS-BRILLOUIN APPROXIMATION. Due also to Rayleigh and Jeffreys. Method of approximate solution of problems, especially in **quantum mechanics**, based on an expansion of the logarithm of the wave function in powers of the **Planck constant.** Useful only when the momentum of a particle changes only by a small fraction of itself in a distance equal to the **de Broglie wavelength** of the particle.

WESTPHAL BALANCE. A **balance** designed to measure directly the **specific gravity** of liquids by observing the loss in weight of a standard plunger which is immersed in the liquid.

WET AND DRY BULB THERMOMETER. See **vapor pressure, methods of measurement;** also **hygrometer.**

WETTING AGENT. A substance that causes a liquid to spread more readily upon a solid surface, owing its action chiefly to its effect in reducing the **surface tension.** Specific wetting agents have been developed in many industries.

WEYL UNIFIED FIELD THEORY. See **field theory, Weyl unified.**

WHEATSTONE BRIDGE. See **bridge, Wheatstone.**

WHEEL AND AXLE. A simple **machine** whose theoretical **mechanical advantage** is the ratio of the radius of the wheel to that of the axle.

WHEELER-FEYNMAN THEORY. See **action at a distance.**

WHIRLWIND. Small cyclonic whirls of air usually not more than a few hundred feet high and several tens of feet in diameter.

WHISKER. (1) The fine, sharpened electrode forced into contact with the semiconductor material in a **semiconductor diode** or point-contact transistor. (See **transistor, point-contact.**) (2) Certain small crystals possessing great **shear strength.** For example, it has been shown that a very small crystal of tin (10^{-4} cm in diameter) can tolerate extremely large strains in bending without **plastic deformation.** This large shear strength, approaching the classical limit, is due to the absence of dislocations

WHISKER RESISTANCE. The resistance of the **whisker** element of a **semiconductor** device.

WHITE COMBINATION POTENTIOMETER. See **potentiometer, White combination.**

WHITE COMPRESSION (WHITE SATURATION). The reduction in gain applied to a television picture signal at those levels corresponding to light areas in a picture with respect to the gain at that level corresponding to the mid-range light value in the picture. The gain referred to in the definition is for a signal amplitude small in comparison with the total **peak-to-peak picture signal** involved. A quantitative evaluation of this effect can be obtained by a measurement of differential gain. The overall effect of white compression is to reduce contrast in the highlights of the picture as seen on a monitor.

WHITEHEAD THEORY OF GRAVITATION. Theory in which the gravitational field is treated as a tensor field in flat space-time. Formally similar to the general theory of relativity (see **relativity theory, general**), although it lacks the equivalence principle. Yields correct values for the three astronomical tests of a theory of gravitation.

WHITE LIGHT. Any one of a variety of **spectral energy distributions** producing the same color sensation as average noon sunlight.

WHITE NOISE. Random noise, such as **shot noise** and **thermal noise**, which has a constant energy per unit bandwidth that is independent of the central frequency of the band. The name is drawn from the analogous definition of white **light.**

WHITE OBJECT. An object which **reflects** all wavelengths of light with substantially-equal high efficiencies, and with considerable **diffusion.**

WHITE PEAK. A peak **excursion** of the television picture signal in the white direction.

WHITTAKER DIFFERENTIAL EQUATION. A second-order equation

$$y'' + \left(\frac{\frac{1}{4} - n^2}{x^2} + \frac{k}{x} - \frac{1}{4}\right) y = 0$$

with **singular points** at 0 and ∞. It is a canonical form of the **confluent hypergeometric equation** found by removing the term in y', the first derivative. Its solutions, sometimes called **Whittaker functions**, are special cases of the **confluent hypergeometric series.**

WHOLE STEP. See **tone, whole.**

WHOLE TONE. See **tone, whole.**

WIDE-BAND IMPROVEMENT. The ratio of the **signal-to-noise ratio** of the system in question to the signal-to-noise ratio of a reference system. In comparing frequency-modulation and amplitude-modulation systems, the reference system usually is a double-sideband, amplitude-modulation system with a carrier power, in the absence of modulation, which is equal to the carrier power of the frequency-modulation system.

WIDE-BAND RATIO. The ratio of the occupied **frequency bandwidth** to the **intelligence bandwidth.**

WIDMANSTÄTTEN STRUCTURE. A structure in which a geometrical metallographic pattern is produced by the generation of a new **phase** within the body of the parent phase. The shape of the particles of the new phase, and their crystallographic orientations, are both related to the orientation of the parent crystal.

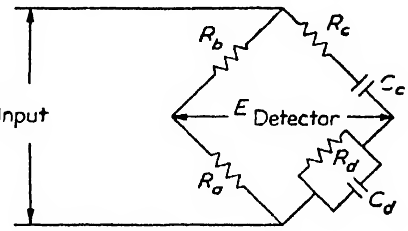
WIDTH. In television, the horizontal dimension of an image. It is generally expressed in inches or feet.

WIDTH CONTROL. In television, the electrical component or circuit that controls the width of the image.

WIEDEMANN EFFECT. See discussion of **magnetostriction.**

WIEDEMANN-FRANZ LAW. The ratio of the **thermal** to the **electrical conductivity** for all metals is proportional to the absolute temperature T, and has a value of $6.11 \times 10^{-9}T$, calorie-ohms sec^{-1} $degree^{-1}$. For 0°C (273° absolute) this gives 0.00000147 calorie-ohm sec^{-1} $degree^{-1}$, which is very close to the observed value for platinum. The Wiedemann-Franz formula is theoretical and its coefficient involves both the **Boltzmann constant** and the electronic charge. (It is also called the **Lorentz number.**) For most metals the ratio as observed is a little higher than that given by the formula, doubtless because of thermal conduction due to other causes than electronic activity.

WIEN BRIDGE CIRCUIT. A resistance-capacitance bridge circuit having a detector/input-voltage magnitude-ratio of zero and a



Wien bridge circuit

detector/input-voltage phase-angle difference of 180° at a frequency

$$f = \frac{1}{2\pi} \sqrt{\frac{1}{R_c R_d C_d C_c}},$$

where $\dfrac{C_d}{C_c} = \dfrac{R_b}{R_a} - \dfrac{R_c}{R_d}$.

WIEN DISPLACEMENT LAW. See **Wien laws.**

WIEN EFFECT. The increase in **conductance** of an **electrolyte** at high **potential gradients.**

WIEN LAWS. From a study of the **spectral energy distribution** of thermal radiation, W. Wien in 1896 arrived at three laws relating to the radiation from a **black body.**

(1) The wavelength λ_m of the spectral distribution, for which the radiation has greatest intensity, is inversely proportional to the absolute temperature T of the black body.

$$\lambda_m T = \sigma.$$

Thus, as the temperature rises, the "peak" of the distribution curve is displaced or shifted toward the short-wavelength end of the spectrum. This is commonly called Wien's "dis-

placement law." The value of the "displacement constant" σ is about 0.2897 centimeter-degree. $\sigma = c_2/4.9651$ in which c_2 is the **second radiation constant,** $hc/k = 1.4384$ cm deg (h is the **Planck constant,** c is the velocity of light and k is the **Boltzmann constant.** 4 9651 is the root of

$$e^{-B} + B/5 - 1 = 0.$$

(2) The emissive power of the black body within the maximum-intensity wavelength interval $d\lambda$ is proportional to the fifth power of the absolute temperature:

$$dE_m = CT^5 d\lambda.$$

Subsequent work by Planck and others gives the value of the constant C as about 1.288×10^{-4} erg/cm^3 sec deg^5.

(3) Wien's third law is an attempt to express the spectral energy distribution of radiation from the black body at temperature T, as follows:

$$dE_\lambda = A\lambda^{-5}e^{-B/\lambda T}d\lambda,$$

in which dE_λ is the **emissive power** within the wavelength interval $d\lambda$ and A and B are constants to be empirically determined.

The first and second laws are in accord with thermodynamic theory and with the **Planck equation,** and also agree very accurately with experiment The third law is empirical, but is almost identical with the Planck equation at short wavelengths, and is more simple to use However, Wien's distribution law fails at longer wavelengths.

WIEN RADIATION LAW. See **Wien laws.**

WIENER EXPERIMENT. Wiener placed a thick photographic emulsion on a front-faced mirror. The emulsion was then exposed by monochromatic light incident normal to the surface. Upon development of the emulsion, it was found that **stationary waves** had been set up in the emulsion between the incident and the reflected light. The **nodes** of the stationary waves were found at the nodes of the electric vector, not at the nodes of the magnetic vector.

WIERL EQUATION. The intensity of the electron beam scattered into the angle θ by diffraction from a gas of molecules having atoms j, k (with atomic scattering factors A_j, A_k) a distance r_{jk} apart is

$$\Sigma_{j\,k} A_j A_k \frac{\sin xr_{jk}}{xr_{jk}}$$

where $x = 4\pi/\lambda \sin \frac{1}{2}\theta$ and λ is the electron wavelength.

WIGNER FORCE. Short range force of non-exchange type postulated phenomenologically as part of the interaction between nucleons.

WIGNER NUCLIDES. A special case of **mirror nuclides.** Pairs of odd-mass number isobars for which the atomic number and the neutron number differ by one, and in which the numbers of protons and neutrons are so related that each member of the pair would be transformed into the other by exchanging all neutrons for protons and vice versa.

WIGNER-SEITZ METHOD. A technique for calculating the **band structure** of a metal. Each ion is supposed to be surrounded by a sphere containing one **atomic volume,** and a wave function computed so that its gradient is zero at the surface of the sphere. This spherical symmetry makes the calculation very simple, but not very reliable

WIGNER THEOREM. A prediction from quantum theory, stating that in a **collision of the second kind, angular momentum** of **electron spin** is conserved. That is, for all possible transfers of energy, the one most likely to occur is that in which the total resultant spin of the two atoms remains unchanged.

WILLIAMS REFRACTOMETER. See **refractometer, Williams.**

WILSON CLOUD CHAMBER. See **cloud chamber.**

WILSON ELECTROSCOPE. Discussed under **electroscope.**

WILSON EXPERIMENT. The theory of the **electromagnetic field** in dielectrics requires that if a dielectric move across a magnetic field, an electric polarization should be produced in it at right angles to the field and to the motion; just as in a conductor, likewise moved, electric induction is set up. The question was tested by H. A. Wilson in an experiment which has become classic. A hollow cylinder of dielectric material, coated on its inner and outer cylindrical surfaces with metal, was rotated about its axis in a mag-

netic field whose lines of force were parallel to the axis. The metal coatings were connected to a sensitive electrometer, which registered a charge, reversing with the reversal of the field, and having both the sign and the magnitude required by the theory.

WIMSHURST MACHINE. See **static machines.**

WIND DEVIATION. The angle between the direction of the wind and the direction of the **pressure gradient.**

WIND EQUATIONS. Equations for velocity of **air parcels,** which are usually expressed in terms of the pressure gradient, the density of the air, the latitude, the angular velocity of the earth, and the curvature of the parcel's path. The complexity of this relationship is due to the fact that many factors influence the movement of air in any quasi-horizontal plane at or above the surface of the earth. In the friction layer, frictional forces play an important role. Convergence and divergence also play their part in determining air flow. Isallobaric fields have some influence. But, in general, three major forces play the main roles in establishing the winds. They are:

(1) The Coriolis or deflective force due to the earth's rotation which is given by $2\omega V\rho \sin \phi$

(2) The pressure gradient of the atmosphere which is given by dp/dx

(3) Centrifugal force due to curvature of path of air parcel, which is given by $V^2\rho/r$, where ω is the angular velocity of the earth, V is the velocity of the air parcel, ρ is the air density, ϕ is the latitude, r is the radius of curvature of the parcel's path, and dp/dx is the pressure gradient.

If air movement is unaccelerated, these three forces are the only factors involved in determining the wind. When other forces are active, accelerations and decelerations alter equilibrium conditions among the three principal forces. However, equilibrium conditions hold, except under the excessive influence of one or more of the minor forces, and winds are generally determined by the balance among the three main forces.

There are several cases possible for establishing a balance of forces among the three and thus the wind equations may take several forms.

WIND, GRADIENT. See **gradient wind.**

WIND INCLINATION. The angle which the wind direction makes with the direction of the **isobar** at the place of observation.

WIND, KATABATIC. See **katabatic wind.**

WIND ROSE. Any diagram showing features of wind direction and velocity in the form of a hub, with spokes of a wheel representing direction or velocity values or both. The most common wind rose is one in which the length of the spokes of the wheel extending into the cardinal directions represents the frequency of winds from that direction.

WIND VANE. An arrow with considerable tail surface. Air flowing past the tail surface keeps the arrow pointed in the direction from which the wind is coming. The vane is usually mounted some 20–30 ft above the ground or water level.

WIND, VEERING. See **veering wind.**

WINDS. (See also **circulation of the atmosphere.**) Winds can be divided into four categories:

(1) Gradient winds blow in accordance with the existing pressure gradient, centrifugal force and **Coriolis force.**

a. Cyclonic winds blow counterclockwise about regions of relatively low pressure in the northern hemisphere and clockwise in the southern hemisphere.

b. Anticyclonic winds blow clockwise about regions of relatively high pressure in the northern hemisphere and counterclockwise in the southern hemisphere.

(2) Geostrophic winds blow in accordance with the pressure gradient, but only where the pressure gradient is balanced by the Coriolis force. They are, therefore, winds which blow in straight or nearly straight lines over the earth. Geostrophic winds are not possible at the equator because there is no Coriolis force present.

(3) Cyclostrophic winds blow cyclonically in both hemispheres in wind systems where the pressure gradient is balanced by centrifugal force in the absence of the Coriolis force. Cyclostrophic winds occur near the equator as hurricanes and other local less intense vortices.

(4) Antitriptic winds are small-scale, short duration winds which blow, in general, along

the pressure gradient. Land and sea breezes are of this type.

In general, winds are mainly gradient winds. Many strictly local winds blow over relatively small regions. Most of these occur where there is sharp contrast in surface temperature over a relatively small distance or where terrain is highly irregular. Sea breezes blow from cool water to heated land during the heat of day. Land breezes blow from cooled land to warmer water during the cool of the night. Valley breezes blow upslope in valley-hill terrain during sunny days, and mountain breezes blow downhill in a reverse manner during darkness. Mountain breezes often become very strong and extremely variable as a result of large-scale eddies and Venturi effects in mountain passes. (See also **circulation of the atmosphere.**)

WINDING, COSINE. A type of winding used in the deflection yoke of a magnetically-deflected **cathode-ray tube** to prevent changes in focus with deflection.

WINDOW, CAPACITATIVE. Conducting diaphragms extending into a **waveguide** from top, and/or bottom. They produce the effect of a capacitive **susceptance** shunted across the waveguide at that point.

WINDOW, INDUCTIVE. Conducting **diaphragms** extending into a **waveguide** from one or both side-walls of the waveguide. The diaphragms in this position produce the effect of an inductive susceptance shunted across the waveguide at that point.

WINDOW, RESONANT. A conducting **diaphragm** containing elements of both the inductive and capacitive **windows** that gives the effect of a parallel L-C circuit shunted across the point at which the diaphragm is placed.

WIRE GRATING, CONFORMAL. See **conformal wire grating.**

WIREPHOTO. See **fascimile.**

WIRE RECORDING. A method of **recording** involving the longitudinal magnetization of a moving magnetic wire.

WOBBULATOR. A device, usually mechanical, used to frequency-modulate an **oscillator** for test purposes. A small trimmer capacitor rotating at constant velocity across the frequency-determining network of the oscillator is an example.

WOLLASTON PRISM. Discussed under **prism, Rochon.**

WOOD EFFECT. The **alkali metals** are found to be transparent to light in the **ultraviolet.** According to the **free electron theory of metals,** the effect should occur for light of wavelengths less than

$$\lambda_0 = 2\pi(mc^2/4\pi Ne^2)^{1/2}$$

where e and m are the charge and mass of the free electrons, of number density N, and c is the velocity of light.

WOOFER. A low-frequency **loudspeaker** used in high fidelity systems. It is customarily used with a **cross-over network** and a **tweeter.**

WORD. •An ordered set of characters having a meaning and considered as a unit. **Digital computers** commonly use a fixed word length (that is, a fixed number of characters) which is a characteristic of each computer

WORK. The work done by a force on a particle during a given displacement is the space integral of the force over the path taken by the particle Specifically if the force is **F** and the elementary displacement of the particle $d\mathbf{r}$, where **r** is its position vector, the work done is

$$\int_A^B \mathbf{F}\cdot d\mathbf{r}$$

where the path extends from point A to point B. At every point $d\mathbf{r}$ is directed along the path. (See **conservative system; work-kinetic energy theorem.**)

WORK FUNCTION, ELECTRONIC. The energy (usually measured in **electron-volts**) needed to remove an electron from the **Fermi level** in a metal to a point an infinite distance away outside the surface. The work function is important in the theory of **thermionic emission.** In that case, as for example, that of an electron escaping from the heated, negatively-charged filament of a vacuum tube, the work function may be called the thermionic work function. **Photoelectric emission** has a corresponding work function.

WORK FUNCTION, THERMODYNAMIC. See **free energy (2).**

WORK HARDENING. Single crystals of pure metals show rapid **plastic deformation** at first, but this is often followed by a considerable increase in the shear strength. It is thought that this is due to the motion of **dislocations** along two different **slip planes,** which intersect and hence impede each other.

WORK-KINETIC ENERGY THEOREM. The work done by the resultant force on a particle during a given displacement is equal to the change in kinetic energy experienced by the particle during this displacement. It also holds for a rigid body and for incompressible fluids.

WORK, MAXIMUM. The maximum amount of work which can be obtained from a process, i.e., when it takes place reversibly.

WORK, PRINCIPLE OF VIRTUAL. When a system of particles subject to constraints is in equilibrium under the action of a set of impressed external forces the total work done by these forces when the particles undergo small displacements compatible with the constraints (so-called virtual displacements) is zero. Analytically put

$$\sum_{i=0}^{n} \mathbf{F}_{ie} \cdot \delta \mathbf{r}_i = 0$$

where the impressed external force on the ith particle of the system is $\mathbf{F}_{ie}$ and its virtual displacement is $\delta \mathbf{r}_i$. The sum is taken over all the particles.

WORK, UNITS OF. See units of **energy.**

WORLD. Used as adjective as in world scalar, world vector, etc., to emphasize that the transformation properties referred to are related to **Lorentz transformations** as opposed to rotations in three dimensions. Hence also world line (see **space-time path**), world velocity (see **four-velocity**).

WOW. Speed variation in reproduced sound, i.e., a low-frequency **flutter.**

WRONSKIAN. Let $y_1, y_2, \cdots, y_n$ be functions of x, each having derivatives $y_i', y_i'', \cdots, y_i^{(n-1)}$, then the **Wronskian** of the functions is the **determinant**

$$W = \begin{vmatrix} y_1 & y_2 & \cdots & y_n \\ y'_1 & y'_2 & \cdots & y'_n \\ \cdot & \cdot & \cdot & \cdot \\ y_1^{(n-1)} & y_2^{(n-1)} & \cdots & y_n^{(n-1)} \end{vmatrix}.$$

If $W \neq 0$, the n functions are linearly independent. When the y_i are solutions of a linear differential equation of nth order, evaluation of the Wronskian is a simple means for deciding whether or not the n functions give the complete solution of the differential equation.

WULF ELECTROMETER. The distinctive characteristics of this instrument are discussed under **Electrometer.**

WÜLLNER LAW. The modification of the **osmotic** properties of water by a dissolved substance, notably the reduction of the vapor pressure is a direct function of the concentration of the solute.

WYE RECTIFIER. See **rectifier, wye.**

X

X. (1) Reactance (X), capacitative reactance (X_c), inductive reactance (X_L), specific acoustic reactance (X). (2) Rectangular coordinates (x,y,z). (3) Mole fraction in liquid (X). (4) Mole ratio in liquid (x). (5) Distance above datum plane in direction of flow (x). (6) Acoustical volume displacement (X). (7) Distance between object and principal focus of object space (x). (8) Distance between image and principal focus of image space (x').

X-RAYS. Electromagnetic radiation of wavelengths less than about 100 A, which have been shown by **x-ray diffraction** methods to be essentially in the range of 0.1–100 A, produced: (1) when electrons, accelerated in a vacuum, strike a target and lose kinetic energy in passing through the strong electric fields surrounding the target nuclei, thus giving rise to **bremsstrahlung** and resulting in a continuous x-ray spectrum; (2) by the transitions of atoms from higher energy states to K, L, $\cdots$ energy states, thus giving rise to characteristic x-rays. The term x-rays is not used to refer to the characteristic radiation from an element of atomic number Z less than 10, since the wavelengths of such radiation exceed those in the x-ray range. However, every element has its characteristic x-ray spectrum, when used as a target, although according to the **Duane and Hunt law** the radiation also depends on the accelerating voltage. X-rays may be detected photographically, by **fluorescence**, or by the **ionization** they produce in gases. Their capacity for penetrating considerable thicknesses of solids is exploited in medicine, while the diffraction effect is used in **x-ray analysis** of **crystal structure.**

X-RAY ANALYSIS. The **diffraction** of **X-rays** by crystalline solids is a powerful technique for the identification and solution of their **crystal structures.** Various experimental methods are used. In the **Laue method** radiation covering a wide range of wavelengths is passed through a stationary crystal, and the diffracted beams caught as spots on a photographic plate. In other methods, a monochromatic beam falls on the crystal, which is rotated so that various atomic planes come into position, the intensity of the reflection being measured either by the ionization it can produce (**Bragg spectrometer**) or on a photographic plate (**rotating crystal, Weissenberg methods**). A useful method for rapid identification, and the measurement of **lattice parameters** is the **Debye-Scherrer-Hull** method where the beam falls on a powdered sample, forming a characteristic ring pattern photograph.

X-RAY ANALYSIS TRIAL. A **crystal structure** may often be determined from an **x-ray analysis** by guessing the most likely structure, calculating a trial x-ray diffraction pattern, and comparing this with the observed pattern. (See **Patterson-Harker method** and **Patterson map.**)

X-RAY(S), CHARACTERISTIC. X-rays which are characteristic of the element in which they are produced. Their emission results from rearrangements of electrons in the inner shells of atoms. For elements of atomic number of 20 or greater, the energies are grouped in similar series. (See ***K*-radiation, *L*-radiation,** etc.) Commonly the target of an x-ray tube emits both characteristic x-rays and continuous **x-rays.** (See **bremsstrahlung.**)

X-RAY(S), CONTINUOUS. The electromagnetic radiation of continuous spectral distribution produced by **bremsstrahlung,** for example, when electrons strike a target. The wavelengths of the continuous x-rays vary from a minimum, corresponding to a photon energy equal to the maximum kinetic energy of the incident particles, to indefinitely large values. For a given tube-current, the intensity associated with each wavelength is dependent on the material and thickness of the target, and on the potential difference applied to the tube. The continuous spectrum produced by very

high-velocity electrons from, for example, a **betatron** may extend into or beyond the γ-ray range of wavelengths. However, such radiation is still referred to as x-rays, the term γ-rays being reserved for electromagnetic radiation emitted by nuclei.

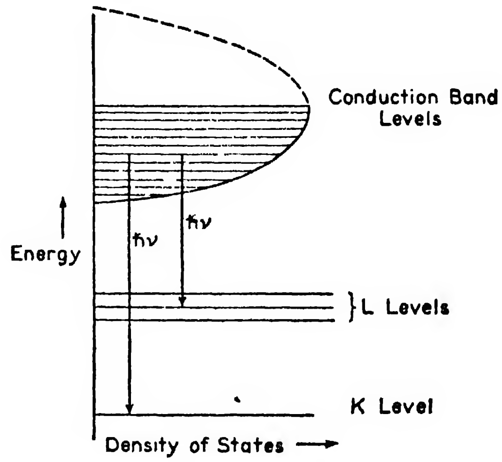
X-RAY CRYSTALLOGRAPHY. See **x-ray analysis** and **crystal structure.**

X-RAY DETECTION. **X-rays,** being **quanta** of many electron volts energy, are capable of ionizing material in which they are absorbed. The ionization may be observed directly, as in a gas-filled **ionization chamber,** or photographically or by associated **fluorescence** effects. If it is necessary to obtain the spectrum of the x-rays, the analysis is effected by diffraction from a crystal, as in the **Bragg spectrometer.**

X-RAY DIFFRACTION. Early attempts to diffract x-rays by slits, gratings, etc., were unsuccessful. It was then realized that they might have wavelengths as small as the actual interatomic distance in a solid. The experiment of Friedrich and Knipping confirmed von Laue's theoretical calculation of the type of pattern to be expected for the diffraction of a beam of x-rays by the regular atomic lattice of a crystal (see **x-ray analysis and crystal structure**). When the diffracting material is not in an ordered state, as in a gas, the x-rays are diffracted as if by each atom independently. The characteristic x-ray diffraction pattern for liquids consists of a few rather diffuse rings. These may be interpreted as meaning that the liquid resembles a microcrystalline material of extremely small grain-size, but a more acceptable description can be found in terms of the **radial distribution function** without requiring the existence of grain boundaries. The radial distribution function completely determines the diffraction pattern.

X-RAY(S), EFFECTIVE WAVELENGTH. Wavelength of monochromatic x-rays which undergo the same percentage **attenuation** in a specified filter as the heterogeneous beam under consideration. The term was originated by Duane; his specified filters were 1 mm Cu or 3 mm Al and he determined attenuation of the monochromatic rays by means of a **spectrometer.**

X-RAY EMISSION SPECTRA. The relatively sharp K- and L-levels of atoms in a solid may be ionized by electron impact and filled by electrons dropping from the **conduction band** in a metal or from a filled band in an insulator. The spectrum of the emitted



radiation gives directly a (rather smudged) representation of the shape of the band, since the intensity of radiation emitted with a particular frequency will depend on the number of electrons available with the appropriate energy, i.e., on the energy density of filled levels in the band. (See figure.)

X-RAY HARDNESS. The penetrating power of x-rays, which is an inverse function of the **wavelength.**

X-RAY(S), HETEROCHROMATIC. See **x-rays, heterogeneous.**

X-RAY(S), HETEROGENEOUS. X-rays of a broad range or considerable number of frequencies.

X-RAY(S), HOMOGENEOUS. X-rays of a single frequency or of a narrow band of frequencies.

X-RAY LEVELS. See discussion under **x-ray series.**

X-RAY(S), MONOCHROMATIC. See **x-rays, homogeneous.**

X-RAY REFLECTION, INTEGRATED. See **integrated x-ray reflection.**

X-RAY SPECTRA. When **cathode rays** fall upon a specimen of some element the resulting **x-rays** consist of a continuous spectrum

upon which are superimposed certain groups of much sharper lines characteristic of the element. These lines (see **K-line, L-line,** etc.) correspond to transitions between the inner **energy levels** of the atom, and their frequencies obey the **Moseley law.** (See **x-ray(s), characteristic.**)

X-RAY SPECTRA, INTENSITY OF. The relation between the integrated reflection $\rho(hkl)$ and the **structure amplitude** $F(hkl)$ for the (hkl) plane is given by

$$\rho(hkl) = \frac{N^2e^4}{m^2c^4}\,|F(hkl)|^2\,\frac{\lambda^2}{2\mu\sin^2\theta}\cdot\frac{1+\cos^2 2\theta}{2}$$

where N is the number of unit cells per cm^3 of crystal, m is the mass of the atom, λ the wavelength of the x-rays, μ their absorption coefficient in the crystalline material, and θ the **glancing angle.**

X-RAY SPECTROGRAM. A record of an x-ray diffraction pattern.

X-RAY SPECTROGRAPH. An apparatus used to record **x-ray diffraction** patterns, such as an **x-ray spectrometer** equipped with photographic or other recording apparatus.

X-RAY STRUCTURE. The **atomic** or ionic **structure** of substances as determined by **x-ray diffraction** patterns obtained by the passage through it of x-rays.

X-RAY UNIT. Same as **x-unit.**

X-UNIT (XU). A unit used in expressing the wavelengths of x-rays or γ-rays. It is about 10^{-11} cm, or 10^{-3} angstrom. Accurately, 1 Xu = $1.00202 \pm 0.00003 \times 10^{-3}$ angstrom.

X WAVE. See **extraordinary-wave component.**

XENON. Gaseous element. Symbol Xe. Atomic number 54.

XI. (1) Propagation flux density (Ξ). (2) Displacement component of sound-bearing particle (ξ).

Y

Y. (1) Admittance (Y), admittance with plate load, or grid or input (y_g), admittance, output (y_p). (2) Rectangular coordinates (x,y,z). (3) Yttrium (Y). (4) Mole fraction in vapor (y). (5) Mole ratio in vapor (Y). (6) Depth or height (y). (7) Height of object (y). (8) Height of image (y'). (9) Altitude (y). (10) Transverse acoustical displacement (y). (11) Young modulus of elasticity (Y). (12) Super-compressibility factor (y).

Y-CONNECTION. Three-phase a-c equipment is wound with three wires whose currents differ 120° electrically in **phase.** The windings can be connected either in **Y** or **delta.** In balanced electrical condition, voltages and currents are the same in all coils. In the Y-connections one end of all three coils is connected in a common joint, and leads from each of the other ends constitute the three-phase line (See also **delta connection.**)

Y-JUNCTION. See **junction, Y.**

Y-NETWORK. See **network, Y.**

Y-RECTIFIER. See **rectifier, wye.**

YARD. Unit of length, abbreviation yd. (1) British. The imperial yard is the length equal to that of the standard yard, i.e., to the distance between two parallel scratches on a standard bar maintained in London, under specified conditions of temperature and pressure. The imperial yard is equivalent to 0.9144004 meter. (2) U.S. The U.S. yard is defined as exactly 3600/3937 meter.

YARKOVSKY EFFECT. Force on a rotating body moving around the Sun produced by uneven emission of radiation due to a phase lag in the surface temperature. Causes the body to spiral outwards when spin and orbital angular momentum are parallel. Negligible for the planets but not for meteors of radius $\lesssim$ 1 cm.

YIELD POINT. The minimum unit **stress** at which a structural material will deform without an increase in the **load** is called the yield point. Some materials do not have a yield point and in others it is not a well-defined value. Consequently, in these cases it has become common practice to use a quantity called the yield strength. The yield strength is the unit stress corresponding to a specific amount of permanent unit **deformation.**

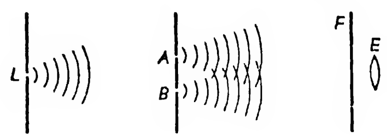
YLEM. The primordial substance from which the chemical elements may have been derived. (See **nucleogenesis.**)

YOKE. The frame upon which is wound the horizontal and vertical deflecting coils for a magnetic deflection cathode-ray tube (See **kinescope.**)

YOUNG CONSTRUCTION. A graphical method for tracing a ray of light through a spherical boundary between media of different refractive indices.

YOUNG-HELMHOLTZ THEORY. The original theory of color vision. It assumes the existence in the eye of three mechanisms each sensitive to one of the three primary colors, red, green and blue. It accounts for some of the observed phenomena of color vision, but not for others The theory is convenient for many purposes but has been modified by later students. (See **Ladd-Franklin theory.**)

YOUNG INTERFERENCE EXPERIMENT. In 1801 Thomas Young made the epochal discovery of the **interference** of light waves, by means of an experiment which has become classic. Light from a narrow slit L falls on a plate in which are two parallel slits, A, B, very close together, so that from the further side of the latter there emerge two exactly similar wave trains. (See figure.) These



Light from single source L gives rise to two wave trains at A and B, which produce interference fringes on screen F

overlap in the region beyond AB and produce interference. If a screen F is placed at some distance from AB, alternate bright and dark bands or fringes appear on it, parallel to the two slits. If a translucent screen is used (or in the case of white light, a plate of colored glass acting as a color filter), these bands may be viewed by means of a magnifier beyond it at E, or better, a low-power micrometer eyepiece, with which the width of the band-interval can be measured.

It is easy to show from the elementary theory of interference that if $AB = s$, if the distance from AB to F is x, and if the wavelength of the light is λ, the distance on the screen between any two consecutive dark bands or any two consecutive bright bands is $b = x\lambda/s$. Therefore if b, s, and x are measured, we have at once a means of determining the wavelength: $\lambda = bs/x$.

Other devices have proved more satisfactory than the pair of slits, such as the Young "biprism," the **Fresnel mirrors**, or the **Lloyd mirror**; each of which produces a double virtual image of the slit L to serve as the two wave-train sources A and B.

YOUNG MODULUS. The **elastic modulus** corresponding to simple tension, the strain being measured parallel to the tension. In the case of an elastic solid rod or wire, the Young modulus is the ratio of the tensile **stress** to the associated **linear strain.** In any **isotropic** solid, Young's modulus is

$$E = \frac{9\mu B}{\mu + 3B}$$

where μ is the **shear modulus,** and B is the **bulk modulus.**

YTTERBIUM. Rare earth metallic element. Symbol Yb. Atomic number 70.

YTTRIUM. Rare metallic element. Symbol Y or Yt. Atomic number 39.

YUKAWA POTENTIAL. A potential function of the form $V = (V_0/r)(e^{-r/b})$. It is used to describe the **meson field** about a nucleon. The Yukawa potential is employed rather frequently as one shape of nuclear potential well that can be used in attempts to fit theory with experimental results, for example, in high energy scattering. It is characterized by (1) infinite strength at $r = 0$, (2) an exponential tail extending with appreciable strength to larger r rather than a Coulomb potential. (See **potential, nuclear; nuclear forces.**)

Z

Z. (1) Atomic number (Z) (2) Gram-equivalent weight (Z). (3) Molecular collision frequency (Z). (4) Distance above datum plane (z). (5) Modulus of section (Z) (6) Impedance or acoustic impedance (Z), specific acoustic impedance (z) (7) Rectangular coordinates (x,y,z). (8) Radius of circle of least confusion (Z). (9) Complex variable ($\mathbf{z}$).

Z-AXIS MODULATION. The intensity modulation of a **cathode-ray tube** by variation of the grid-cathode voltage.

Z MODULATION. See **z-axis modulation.**

ZEEMAN EFFECT. An effect of a moderately intense magnetic field upon the structure of the spectrum lines of a gas when subjected to its influence The phenomenon, sought unsuccessfully by Faraday and finally observed by Zeeman in 1896, consists in the splitting up of each line into two or more components In the simpler cases, when the source is viewed at right angles to the field, there are three components, of which the middle one has the same frequency as the unmodified line This component is plane-polarized to vibrate parallel with the field, while the two side components vibrate at right angles to the field. When the source is viewed in the direction of the field, there are only two components, displaced in opposite directions, and circularly polarized in opposite senses. (See **polarized light.**) These phenomena constitute the so-called "normal" Zeeman effect.

With most lines, however, the number of components is greater, in some cases reaching twelve or fifteen, the "anomalous" Zeeman effect. They are symmetrically arranged and symmetrically polarized. The displacements, as in the simpler case, are proportional to the magnetic field intensity H, and are always expressible, in wave numbers, as rational multiples of the displacement in the normal effect, which is $4.67 \times 10^{-5}H$ (reciprocal centimeter), a quantity known as the "Lorentz unit." The anomalous Zeeman effect is explained by assuming that the magnitude of the term splittings for a given field strength is not the same for all terms, but differs according to the values of the quantum numbers L and J.

Closely related to the Zeeman effect are two others, the **Paschen-Back effect,** produced by very strong magnetic fields, and the **Back-Goudsmit effect,** observed with the spectra of elements having a nuclear magnetic moment, such as **bismuth.** (See also **Stark effect.**)

ZENER CURRENT. The current through an insulator in a very intense electric field, sufficient to excite an electron directly from the **valence band** to the **conduction band.**

ZENER VOLTAGE. (1) The field required to excite the **Zener current,** of the order of 1 volt per unit cell, or 10^7 volts/cm (2) The voltage associated with that portion of the reverse volt-ampere characteristic of a **semiconductor,** wherein the voltage remains substantially constant over an appreciable range of current values Since the effect is considered by some to be analogous to **breakdown** in a **gas discharge,** it is sometimes referred to as a **Townsend discharge** or **electron avalanche.**

ZERO. The number which has the fundamental properties

$$a + 0 = a, \quad a \cdot 0 = 0,$$

and

$$0/a = 0, \quad \text{if } a \neq 0,$$

where a is any number Division by zero is not defined and is not a permissible operation. (See also **matrix, null.**)

ZERO BEAT. **Heterodyning** with zero frequency difference.

ZERO-BEAT RECEPTION. **Homodyne detection.**

ZERO BRANCH. See **Fortrat parabola.**

ZERO GEODESIC. See **null geodesic.**

ZERO LINE. See **Fortrat parabola.**

ZERO-LINE GAP. See **Fortrat parabola.**

ZERO OF A FUNCTION. A value of the **argument** for which a function vanishes. Thus, a zero of $f(x)$ is a **root** of the equation $f(x) = 0$.

ZERO POINT ENERGY. The kinetic energy remaining in a substance at the absolute zero point of temperature. According to quantum mechanics, a simple harmonic oscillator does not have a **stationary state** of zero kinetic energy. The **ground state** has still one half quantum, $h\nu$, of energy, and the motion corresponding thereto. This agrees with the **uncertainty principle,** which does not permit the oscillator particle to be absolutely at rest exactly at the origin. In solids the zero-point energy is distributed in the normal modes of **lattice vibration,** and may be an appreciable term in the **binding energy** of the crystal, especially in hydrogen, helium, rare gases, etc. The motion may be observed in **x-ray diffraction,** but does not contribute to electronic resistivity. (See also **oscillator, harmonic.**)

ZERO POINT ENTROPY. According to the third law of thermodynamics (see **thermodynamics, third law**) the entropy of a system in equilibrium at the absolute zero must be zero. Such systems, as for instance a glass, which can have finite entropy at absolute zero are not in thermodynamic equilibrium.

ZERO SHIFT. In a **balanced magnetic amplifier,** that output which occurs with zero control signal because of **drift.**

ZERO STABILITY. Zero stability of a **balanced magnetic amplifier** is expressed in terms of the maximum **zero shift** which occurs over a given period of time with given changes in operating conditions.

ZERO SUBCARRIER CHROMATICITY. The **chromaticity** which is intended to be displayed when the **subcarrier** amplitude is zero.

ZETA. Displacement component of sound-bearing particle (ζ).

ZETA POTENTIAL. See **electrokinetic (zeta) potential.**

ZIG-ZAG RECTIFIER. See **rectifier, zig-zag.**

ZIG-ZAG REFLECTIONS. Multiple **ionospheric reflection.**

ZINC. Metallic element. Symbol Zn. Atomic number 30.

ZIRCONIUM. Metallic element. Symbol Zr. Atomic number 40.

ZITTERBEWEGUNG. The oscillatory motion of a **Dirac electron** as given by the **Heisenberg equation of motion** when applied to the position operator. For a free electron of energy w, the frequency of this motion is $2w/h$.

ZODIACAL LIGHT. Sunlight reaching the earth after scattering from other bodies of the solar system, chiefly from meteoritic dust of radius $\sim 10^{-3}$ cm. Predominance of forward scattering causes light to be visible in the east just before dawn and in the west just after sunset.

ZONAL ABERRATION. **Spherical** or monochromatic **aberration** of a lens of wide **aperture** due to the fact that the **refracting power** is different for different zones concentric at the axis.

ZONAL HARMONIC. See **harmonic.**

ZONE AXIS. The axis through the center of a **crystal** which is parallel to the edge of a zone.

ZONE, INTERFACIAL. The boundary area between two **phases,** consisting of the boundary particles of each phase if, in the particular case, they may be regarded as composed of particles.

ZONE LEVELING (PERTAINING TO SEMICONDUCTOR PROCESSING). The passage of one or more molten zones along a **semiconductor** body for the purpose of uniformly distributing **inpurities** throughout the material.

ZONE OF A CRYSTAL. A set of faces of a **crystal** meeting (or capable of meeting if extended) in a series of edges, all of which are parallel.

ZONES OF SILENCE. Regions surrounding a sound source in the atmosphere in which sounds from the source become inaudible, although they can again be heard at greater distances.

ZONE PLATE. See **diffraction, half-period elements or zones.** By the use of a plate on which are alternate transparent and opaque

circular zones of such size as to transmit only every other half-period element of the wave front, an image of the source point may be formed somewhat as by a lens. The diameters of the zones on the zone plate will be about as the square root of the number of the zone counting out from the center. Because of the shortness of the wavelengths of visible light, these zones on the zone plate are too close together to make this a useful lens.

ZONE PURIFICATION (PERTAINING TO SEMICONDUCTOR PROCESSING). The passage of one or more molten zones along a **semiconductor** for the purpose of reducing the **impurity** concentration of part of the ingot.

ZOOMAR. See **variable focus lens.**

ZWITTERION. An **ion** carrying charges of opposite sign, which thus constitutes an electrically-neutral molecule with a dipole moment; looking like a positive ion at one end and a negative ion at the other. Most aliphatic amino-acids form such dipolar ions, hence react with both strong acids and strong bases.